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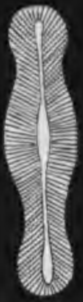
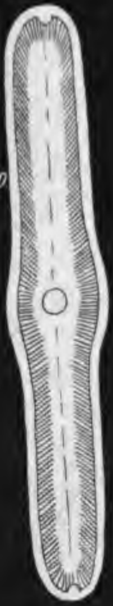
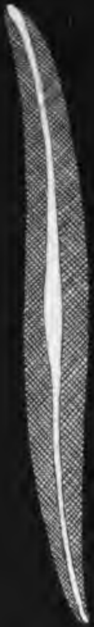


Fig. 61.

Fig. 60





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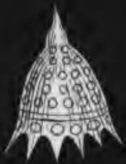

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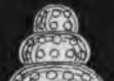

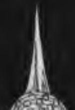

A HANDBOOK

OF THE

MICROSCOPE AND MICROSCOPIC OBJECTS

WITH

DESCRIPTIVE LISTS OF UPWARDS OF 1780 OBJECTS

AND FULL DIRECTIONS FOR OBTAINING, PREPARING,
AND VIEWING THEM.

With Twelve Plates, including Figures of Sixty-one Objects.

BY W. L. NOTCUTT,

AUTHOR OF "THE GEOGRAPHY OF PLANTS," ETC.

LONDON: EDWARD LUMLEY,
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PREFACE.

THE following work does not profess to be strictly original. Its aim is to exhibit a concise and popular synopsis of Microscopical Science, adapted especially for those who have but small means and little time at their disposal; for it is the Author's conviction, that numbers have been deterred from the prosecution of this most interesting study by the costliness of the instruments, books, and apparatus required. In the present day, when very many of the humbler and middle classes are successfully cultivating an acquaintance with the various branches of science, there seemed to be a want of a short work, pointing out the merits, especially of the lower-priced Microscopes, such as should be within the reach of all, even though of very limited resources, and which should also be a guide to the attainment and preparation of the most interesting objects. In aiming to accomplish the latter, the Author has endeavoured to prepare *classified* lists of all such objects; and to point out very concisely their connexion with, and place in, the great scale of organized nature. In the preparation of this part of the work, free use has been made (with the author's kind permission) of Mr. Pritchard's "List of 2000 Microscopic Objects;" in addition to which, however, every source of information accessible to the author has been consulted, including among many others, nearly all the works enun Sect. 212.

The Author is fully aware that the work has m fections: some are unavoidable from the small c which he is limited; and very probably various err detected, although great pains have been taken t as correct as possible. He will esteem the comm of any faults that may be discovered a favour, that be avoided in a second edition, should that be c as it is his earnest desire to make it as useful and "Handbook" as possible. He will also be than the same view) for the communication of any interest not noted in the following pages.

CHELTENHAM, *Dec.* 1858.

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CHAPTER I.

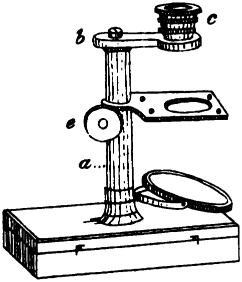
MICROSCOPES.

1. The study of the Microscope is one which presents great and special recommendations and attractions. Amid the pressure of business and the incessant demand on the middle and lower classes for mental or bodily labour, all seek a recreation by which to relax their overtasked powers. To such we recommend the microscope. It is a perennial source of delight and instruction. It is one of the very cheapest amusements, for a very tolerable instrument may be obtained for a few shillings; and at a cost of a few pence additional, a multitude of objects may be acquired and prepared in so permanent a manner, that they may be accessible for inspection and study at any time. It makes no large demand on the time of those who use it, for it may be taken up at any moment, and be as quickly laid aside again. It requires no previous course of preparatory study to use and enjoy it; while, if intelligently employed, it leads its possessor almost imperceptibly to the acquisition of large stores of the most attractive, useful, and varied information. It unveils beauties among the minute and all but invisible tribes which people our earth, which equal, if they do not surpass, anything on which the unassisted eye gazes. It brings before us marvels so strange, and apparently incredible, that all the inventions of romance and fiction are rendered trivial and tame by the side of the facts which it presents to our senses. It does not necessarily send us to search for its wonders in the depths of the sea, or to roam among the productions of foreign climes,

but all around our dwellings we may find, without any cost at all, a thousand strange and beautiful things, the very existence of which we could never have suspected without its aid.

2. Into the principles on which the microscope is constructed, we do not purpose to enter; our limits do not admit of it, neither is it necessary to the end this work has in view. A very luminous and accurate digest of these will be found in Dr. Carpenter's *Microscope and its Revelations*, to which we refer the reader desirous of such information; and Quekett's, Hogg's, Brewster's, and other works referred to in the list of general treatises, at sect. 212, contain similar information. Our object here is very briefly to point out a few of the most useful microscopes, in order to aid the beginner in his choice of an instrument which shall be of real service, and to save him from throwing away money upon those which are needlessly expensive or comparatively inefficient.

3. Microscopes are of two kinds, simple and compound. A simple microscope consists of one or more lenses (or magnifying glasses), either by themselves or mounted on a framework. One of the very best yet brought out is that constructed by Messrs. Field and Son, of New Street, Birmingham; and which gained one of the prizes offered in 1855 by the Society of Arts, for the best microscopes at a fixed low price (fig. 1). It has a cylindrical pillar (*a*) about five inches high, which screws into the lid of the mahogany box, into which the whole packs when not required for use. To the top of the pillar is fixed a horizontal arm (*b*), into the end of which the lenses (*c*) screw. To the stem is attached the stage (*d*), which moves up and down to any required distance from the lens, by means of a rack and pinion (*e*). The mirror (*f*) slides on a ring at the lower part of the stem. Three magnifiers are supplied, which may be used either singly, or two or three combined together. If used jointly, the smallest lens employed should be nearest the object, and the largest nearest the eye. The stage is furnished with four holes, into which a condensing lens for opaque objects, or a stage forceps may be fixed. All these are supplied with the instrument, as also a live box for examining objects in water,—and the whole, including the mahogany case, is sold for 10s. 6d. It is called "the Society of Arts Prize School Microscope," and is so good and cheap an instrument, that it is needless to particularize others. A very useful addition to this microscope would be a small brass or tin pan (fig. 2) about 3 inches long, by 1½



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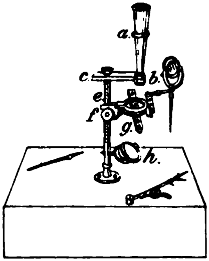

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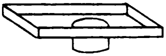

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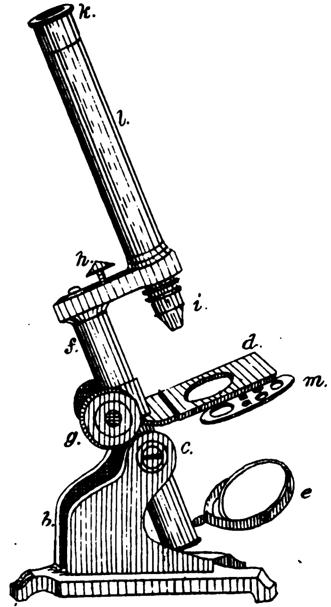

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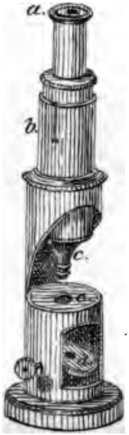

Fig. 3.

or 2 inches wide, and $\frac{3}{8}$ inch deep. In the centre is a hole to which is soldered a tube about 1 inch long, of such diameter as exactly to fit the opening in the stage. A piece of clear glass (not too thin) is then cut to fit the bottom of the tray, and is fixed in and the tray made watertight with putty. When dry it forms a most excellent "dissecting trough" for performing dissections of animal and vegetable substances in water, and could readily be made by any tinman for a few pence. A couple of blocks or inclined planes of wood, nearly as high as the stage, or even a pile of books on each side, will be useful as arm-rests: and these are all that are wanted to make it a very capital dissecting microscope.

4. *Compound Microscopes* differ from *simple* ones, in being provided with a body or tube, at the lower end of which the magnifying lenses (termed *object-glasses* or *objectives*) screw on, and at the opposite or upper end another lens or combination of lenses is placed, called the eye-piece, through which the object is viewed. Usually there is another within the body, called the *field-piece*. These microscopes have great advantages over all others, in the facility with which they are used, and the high magnifying power which is readily obtainable. Among the cheapest are some of French construction. Fig. 3 is a useful microscope at a low price, viz., 15s. It consists of a body (*a*) sliding inside a fixed tube (*b*), and furnished with three magnifiers (*c*) which screw on the end of the body, and may be used either separately or together. The stage (*e*) is flat and fixed, and the light is thrown up through a hole in the centre, by a mirror placed below (*d*). The adjustment is obtained by sliding the body within its sheath till the object appears perfectly distinct. A very good small instrument, with ordinary lenses, is Gould's pocket microscope (fig. 4). This has a brass body (*a*), to the lower end of which the lenses (*b*) can be attached; the whole is then screwed into the arm (*c*), which is fixed by a binding screw to the top of the upright brass pillar (*e*); the back of the pillar is toothed or *racked*, so that by means of the milled head and pinion (*f*) the stage (*g*) is lowered or raised at pleasure. At the lower part of the pillar, the mirror (*h*) is inserted by a pin. The whole packs into a small mahogany box, into the top of which the pillar screws to support the microscope when required for use. This instrument has several advantages over the last. The lenses are of superior workmanship, the adjustment is by rackwork, which renders the obtainal of the focus more easy and precise,

and the mirror has greater freedom of motion. The price i usually £1, 11s. 6d. It would be a great improvement t this microscope, if it were constructed with a cradle-joint at or near the bottom of the pillar, so that it could be placed in any inclined position. The vertical or perpendicular position of a microscope is usually inconvenient, and cannot be used for a length of time without considerable fatigue. This microscope can be used as a simple microscope by screwing the lenses into the horizontal arm without the body.

5. In microscopes with common lenses, a large portion of the light has to be cut off by means of a *stop* (a perforated plate) placed behind the object-glass, so as to admit only the rays which pass through the central portion of the lens. This is rendered necessary by those imperfections which attend all such glasses, called *spherical* and *chromatic aberration*. The former is occasioned by the refraction of the rays at different angles from the different parts of the surface of the lens, consequently meeting in different foci, and producing fog or indistinctness of the image; the latter is owing to the different refrangibility (or, as it is termed, *dispersion*) of the coloured rays composing white light. These also meet in various foci, and produce coloured fringes around the image formed by the rays passing through the middle portion of the lens. Both these imperfections are greatly lessened by the stop, with, however, at the same time, the disadvantage of greatly reducing the illumination which can be thrown upon the object, so that in the case of ordinary lenses of high power, the feeble illumination, together with the necessary exaggeration of these defects, render them practically useless. These serious defects are, however, remedied in what are termed *achromatic* lenses, by employing two different kinds of glass, possessing different refractive and dispersive powers, to form one lens, and so adjusted that the defects of one shall just counterbalance those of the other. This very delicate adjustment has been completely achieved, so that instead of a small part only, the whole lens can be employed, and a clearness of definition, and an insight into the structure of objects obtained, which was wholly impossible with glasses of the ordinary construction. When achromatic object-glasses were first introduced, they were very costly, and only a few years ago there was a difficulty in obtaining a fairly good instrument furnished with such lenses for less than £20 or £30; but now, owing to the vastly increased manufacture, and the greater manipulative

skill of the workmen, especially in France, a very fair instrument may be obtained for from £2 to £10. A very laudable practice has obtained of late years among the makers of these microscopes (which materially diminishes the cost), of supplying the simple stand or mechanical part at a stated price, and selling the lenses, apparatus, &c., separately, affixing a price to each. By this arrangement the student of the microscope is obliged to purchase no more than he really requires, in order to possess an instrument of the desired excellence, while he can, at any time, add either lenses or apparatus, according as he may need or be able to afford them.

6. The cheapest microscope with achromatic lenses that we can recommend, is one made by Baker, 244, High Holborn, London. It is a vertical instrument (so that the stem cannot be inclined) with 3 achromatic lenses, of 1½-inch, 1-inch, and ½-inch focus, and is packed in a mahogany case, price two guineas. But a very superior one is that made by Messrs. Field and Son, of New Street, Birmingham (fig. 5), which obtained the prize given by the Society of Arts in 1855, for the best achromatic microscope, to be sold for £3, 3s. By the terms of the agreement they are bound always to keep it in stock, and of equal quality to the one sent in to the Society for competition. It consists of a strong tripod-foot (*a*) supporting two uprights (*b*), between the upper part of which a hollow stem works on an axis (*c*). This supports the whole of the optical parts of the instrument, which can be adjusted to any position, horizontal, vertical, or inclined at any angle. The stage (*d*) is firmly fixed to the stem, on the lower part of which the mirror (*e*) works, and being provided with a collar or tube which slides on the stem, it can be adjusted to any position, either direct or oblique, in which it may be required, and can also be moved nearer to, or further from, the object on the stage, as may be desired. Within the tubular stem a pillar (*f*) works, which moves up and down within it by means of a rack and pinion, and supports at its upper end a horizontal arm to which the body is attached. Two milled heads (*g*) work this rack and pinion, forming the "coarse adjustment." A smaller milled head (*h*) is attached to the horizontal arm and acts on a lever spring, forming the "fine adjustment." The object should be found and brought as nearly into focus as possible with the first, and it may then be adjusted to perfect definition with the latter. To the lower end of the body (*l*) the lenses (*i*) screw, of which there are two ; and in the

upper end slides the eye-piece (*k*), of which there are also two: thus giving a range of four powers, from 25 to 200 diameters, or, as it used to be expressed, magnifying from about 1000 to 40,000 times. The stage is furnished with a moveable brass ledge, so that a slide may be adjusted to any position, and retain it while being examined. Beneath the stage revolves a diaphragm (*m*), (see sect. 11), which in one position gives a dark background, very useful when opaque objects are to be examined. A perforation at the corner of the stage accommodates a stage forceps. A condensing lens mounted on a separate stand, a live box, dissecting knife, and needle, with some other small matters, are sent out with each instrument. This microscope will, we think, become the standard one for those who cannot afford one of the more perfect and costly instruments. It [illegible] sufficiently good for every ordinary purpose, and though less ornamental than higher priced ones, the foot and supports being of cast iron instead of brass, it is equal or superior to any London-made instrument we have seen under £5. It is capable of showing satisfactorily nearly every object described in this work, and we therefore strongly recommend it. It is termed "the Society of Arts Prize Student's Microscope."

7. Should it be proposed to devote a larger sum to the purchase of a microscope, Messrs. Field and Son supply others at £4, 10s., and £6, 10s., the increase in price being chiefly in the superiority of the lenses; the latter has three object-glasses, a 1½-inch, ¾-inch, and ¼-inch. Mr. Baker, of 244, High Holborn, London, also supplies a very good student's microscope with fine adjustment, 3 achromatic lenses, 1-inch, ½-inch, and ¼-inch, for £6, 10s. The above are all really good instruments, and are similar in general construction to Field's, above described. Other makers turn out very excellent microscopes, though we believe the above are the cheapest. Mr. Dancer of Manchester, Mr. Pillischer, 398, Oxford Street, and Mr. Salmon, 100, Fenchurch Street, London, supply very good instruments. Mr. Pritchard (now Straker), 162, Fleet Street, London, has long had a high reputation for microscopes. But the finest and most perfect English lenses are those of three London makers, viz.,—Mr. A. Ross, 2, Featherstone Buildings, Holborn; Messrs. Powell and Lealand, Seymour Place, New Road; and Messrs. Smith and Beck, 6, Coleman Street. These are so nearly equal in excellence, that it is difficult to say whose are best, but no makers in the whole world have

equalled them as yet; and, therefore, when a sufficient sum can be set apart to obtain one of their instruments, they may be relied on as of the highest excellence attainable. One of their cheapest microscopes is Smith and Beck's student's microscope. The cost of the stand and body complete in a case (but without object-glasses) is £7. The price of object-glass is, $1\frac{1}{2}$-inch, £3; $\frac{2}{3}$-inch, £3, 3s.; $\frac{4}{10}$-inch, £5, 5s.; and $\frac{1}{5}$-inch, £6, 6s.; one, two, or more of these may be employed. Mr. Ross also supplies a microscope with two eye-pieces, and two object-glasses of his best make (1-inch and $\frac{1}{4}$-inch) for £14, 15s. Instruments may be obtained of these makers at a variety of prices, varying from those just mentioned, up to £100, according to the completeness with which they are equipped with optical and auxiliary apparatus. But it would be a waste of space to enter into detail with regard to such instruments, as the present work is rather intended to point out the cheaper forms for the special use of those whose means are limited. Mr. Quekett's and Dr. Carpenter's works will supply full information respecting the higher class of microscopes to those who require it.

CHAPTER II.

ADDITIONAL APPARATUS.

8. UNDER this head a very great variety of appendages might be enumerated, which are intended to supply certain requirements that may arise in practice. We shall here describe a few of the most useful and important, some (those employed in the preparation of objects) being deferred to next chapter.

Micrometer.—This is an instrument intended to obtain accurate measurements of the size of minute objects viewed beneath the microscope, and consists of a plate or slip of glass, with a series of very fine lines ruled upon it at exactly equal distances. These lines vary from the $\frac{1}{100}$ of an inch, to the $\frac{1}{2500}$ part. There are two kinds of micrometers, one fitted to the eye-piece, and the other for placing on the stage. As, however, they are chiefly of service to those pursuing points of special research, and would be comparatively useless to the beginner, we shall not describe them at length here. The cost of a stage micrometer is from 5s. to 10s.; of the micrometer eye-piece from 21s., upwards.

9. *Camera lucida.*—This is an instrument for drawing accurately the magnified image of any object examined by the microscope. It is usually a small prism of glass adapted for attachment to the eye-piece of a microscope, in such a manner that by placing a sheet of paper beneath it, the object having been carefully focussed, and the illumination properly adjusted, the body of the microscope being also placed in a horizontal position, the eye, on looking through the prism, sees a magnified image of the object reflected on the sheet of paper; very little difficulty will then be found in making a correct drawing of it, by tracing a pencil over the image, in its due proportions. The size of the drawing may also be regulated by lessening or increasing the distance of the paper from the prism.

A small plate of highly-polished steel, fitted at an angle of 45°, is sometimes used instead of the glass. Its price varies from 15s. to 34s.

10. *Polarizing Apparatus.*—This is one of the most interesting and important additions to a microscope that can be mentioned. The phenomena which polarized light has disclosed, are some of the most wonderful and magnificent that can be imagined; and a microscope without a polarizing apparatus must be considered incomplete either as an instrument of research, or with respect to the amusement and gratification it is intended to afford. A polarizing apparatus consists essentially of two parts, called the Polarizer and the Analyser; the first inducing that condition of the luminous ray which is termed *polarized*, and the second affording the means of rendering that condition recognisable by the eye.

A variety of means may be employed for polarizing light, but for microscopic purposes, one of the best forms for the polarizer is a Nicol's prism, which consists of two wedge-shaped prisms of Iceland spar, properly adjusted and cemented together by Canada Balsam, and fixed in a brass tube. This is made to screw beneath the stage, so that all the light which is thrown by the mirror on the object to be viewed, must pass through it. Another similar prism (the analyser) is screwed into the adapter, immediately behind the object glass. When this arrangement is used, the Nicol's prism *under the stage* has a milled head, by which it is made capable of revolving on its axis. Another, and better mode of adapting an analyser, is by cementing a thin section of tourmaline (cut parallel to the principal axis) on to a glass plate, which is then fitted into a perforated brass cap, so as to be secure from injury. This cap is made to fit over the eye-piece of the microscope, so as to be able to be revolved at pleasure. Each arrangement has its advantages. The majority of the tourmaline plates which are sold afford a less perfect polarization than the Nicol's prism, but they have the recommendation of giving a larger field of view. Very recently, a most valuable substitute for the tourmaline has been discovered by Mr. Herapath of Bristol. It is a compound of iodine and sulphate of quinine, for the preparation of which he has given full directions in the *Quarterly Journal of Microscopical Science;* but, as it involves much delicate manipulation, and as good crystals are to be purchased, properly mounted, at prices from 4s. upwards, we should recommend the purchase rather than the preparation of the artificial tourmalines. They are usually termed Iodo-sulphate of Quinine, or Herapathite. Their polarizing properties are most perfect.

A very useful addition to the polarizing apparatus is a film of selenite of uniform thickness, mounted between two plates of glass (1 inch by 3): it is used to lay upon the stage beneath those objects which have a somewhat feeble action on polarized light; and greatly increases their beauty and splendour. The cost of a polarizing apparatus, such as described above, may vary from 21s. to 50s.

11. *The Mechanical Stage* is one so contrived, that traversing motions are obtained by means of screws, levers, or rack-work, so as to move an object or slide placed on it in any direction, and to any, even the smallest extent, without touching it with the fingers. This is generally attained by its being composed of two or more plates, to which motion is given as above stated. It is expensive, its cost being from two to four guineas, and is therefore seldom applied to cheap microscopes.

The Diaphragm is a blackened plate, perforated with holes of various sizes, adapted so as to revolve on an axis at about an inch beneath the stage. In one position it is a black stop, so as to give a dark background for opaque objects, and all the holes in it are so adjusted, that their centres correspond with the centre of the stage opening. The use of the diaphragm is to cut off superfluous light when viewing minute transparent objects, and is a very valuable adjunct to a good microscope.

12. *The Frog Plate* (fig. 6) is a plate of tinned or silvered iron, on which frogs or fish are tied, to exhibit the circulation of the blood in their vessels. For this purpose the frog is tied (not tightly) into a wet linen bag by tape, with the exception of one leg. The bag must be fastened by linen threads to the plate by means of the holes in the sides; then the loose leg must be extended, and the toes so held out that the membrane between them may be fully expanded over the central hole; threads, tied to about four of the toes are then fastened to the small holes, and the expanded web or membrane adjusted beneath the microscope, and viewed as a transparent object. When a fish is used, a fin or the tail is the part employed, and must be expanded in the same manner as the foot of the frog, so that the membrane may be flat. For an account of the circulation of the blood, and further directions, see sects. 118-120.

13. *Condensing Lens.*—This is generally a plano-convex lens of considerable size, and of two to three inches focal length. The light is condensed by this upon the object when it is adjusted to the proper focus of the object-glass. Sometimes two lenses are used, the first or larger lens condensing the light upon the second, and the second condensing it upon the object. It is only used for opaque objects. The condensing lens is sometimes mounted on a stem with a universal joint, which fixes into the stage of the microscope; sometimes on a ring sliding on a separate pedestal. Its cost varies from 5s. to 30s. The Lieberkuhn or silver dish, is often used for illuminating opaque objects, either instead of, or subsidiary to, the condenser. It is a small cup of polished silver, screwed on to the adapter to which the object-glass is affixed. By adjusting the mirror so as to throw up a powerful light on the Lieberkuhn, the rays are reflected from the sides and concentrated on the object.

Achromatic Condenser.—This is an arrangement of achromatic lenses beneath the stage, with the view of concentrating the light received from the mirror on the object under examination, and improving the definition of delicate animal and vegetable tissues. It varies in price from 7s. 6d. to £7. Dr.

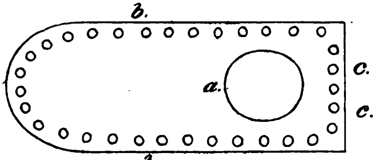

Fig. 6.

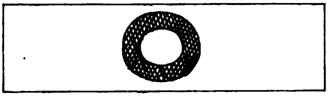

Fig. 7.

Fig. 8.

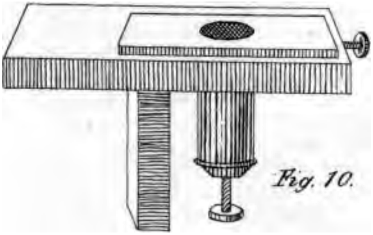

Fig. 10.

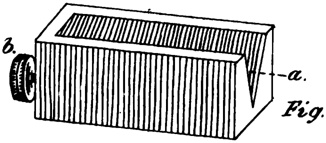

Fig. 11.

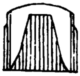

Fig. 9.

by C. F. Cheffins & Sons, London.

Woollaston's condenser for attaining the same end, is a plano-convex lens, with its flat side towards the object, made to slide up and down in a short tube. There should be a stop between the lens and the object.

14. *Dark-ground illumination.*—This is just now a favourite and certainly a very beautiful mode of exhibiting certain objects. The illumination is so managed as to exhibit the object with great brilliancy while the ground is perfectly dark. This may be accomplished tolerably by a due arrangement of the illumination, even without the aid of subsidiary apparatus ; but the best mode is to employ one of the instruments especially contrived for this purpose. One of the cheapest of these is the *spotted lens*, a plano-convex lens of great convexity, with the flat side uppermost, and with a circular disk of dead black paper pasted over the centre of its flat surface. It is made to slide in a tube, so that its distance from the object may be accurately adjusted. Another contrivance is a small triangular prism, so placed that one side shall be in contact with the under side of the object-slide. The spotted lens may be obtained for about 7s. 6d. The other contrivances for the same end are mostly expensive.

15. *Lamps.*—As every student of the microscope will wish to use his instrument in the absence of day-light, a word may be necessary as to the best modes of artificial illumination. Many kinds of lamps and candles are very unfit for microscopic purposes. One of the best lamps is a good argand, well trimmed and supplied with pure sperm oil. A moderator lamp with a shade, and especially if provided with a blue chimney glass, is very good. Messrs. Smith and Beck supply a small camphine lamp excellent for microscope use. Both the eye and the object on the stage should be protected by a screen or shade, or some similar contrivance, from all light but such as passes through the object from the mirror, or is thrown upon it by the condensing lens. If none of the above lamps are at hand, a wax candle is the best substitute.

16. *Fishing Tubes.*—These are tubes of about ⅛th of an inch in diameter, and ground even at both ends. They are used for selecting animalcules, entomostraca, &c., from the jars of water in which they are contained. To use them, press the finger tightly over one end of the tube, and introduce the other into the vessel of water, and carefully and quietly bring it over the animal wished for. Now withdraw the finger, and the water will rush into the tube, carrying the animal with it.

Now apply the finger tightly as at first, and withdraw the tube from the water. The water and the animals it contains will be withdrawn with it, and can be transferred to a slip of glass, or any other apparatus in which it is proposed to view them under the microscope. A pipette, or dropping tube, such as is employed by chemists, is very useful for withdrawing minute portions of precipitates. Employed as recommended for fishing for insects, on withdrawing the finger, the liquid rushes up carrying with it some of the precipitate in its immediate vicinity.

17. *Fishing Net*, for collecting minute aquatic insects, animalcules, &c., from ditches and ponds. It may be made of a ring of stout brass wire, 4 to 6 inches in diameter, with a socket attached for the insertion of a stick. To this ring a net of cambric muslin is attached, made like a landing net. The collector should always carry with him some small wide-mouthed phials, fitted with loose corks, into which to empty the gains his net brings him. The produce of one brook or pond should never be intermixed with that from another, or serious conflicts may take place between the little animals.

We have now described some of the most important appendages to the microscope. A great deal may be done without any of them. Most microscopes are provided with a condensing lens in the first instance; but if the instrument be without one, we should certainly advise the addition of that first. The polarizing apparatus is the next in importance; and the others may be procured as occasion for their use arises, or as they can be afforded.

CHAPTER III.

HINTS.

18. The proper illumination of objects is one of the most important points in microscopic manipulations, for the structure of many objects is scarcely perceptible, unless the light is very exactly adjusted. This being, however, a matter which must chiefly be learned by practice, a very few hints are all

that can be given here. In viewing transparent objects, the plane side of the mirror is best in bright daylight: the concave, for a lamp or candle, which should have the bull's eye lens (when that is used) so close that the rays may fall nearly parallel on the mirror. If the bull's eye condenser is not used, the lamp, &c., should not be more than 5 or 6 inches from the mirror. The latter is seldom required to be more than 3 inches from the object. The centre of the mirror should, especially by daylight, be in the axis of the instrument. For seeing delicate lines, like those on the scales of insects and shells of the navicula, &c., the light should be made to fall obliquely, and in a direction at right angles to the lines to be viewed. * For such objects, Mr. Pritchard recommends the black-ground illumination. Place the mirror out of the axis, and direct it so as to illuminate the field of view, then gently turn it, till only the object appears bright. See also sect. 14.

19. The best light for objects in general, is that reflected from a white cloud on a bright day; but an Argand's moderator, or camphine lamp, or a wax candle, with the bull's eye lens, is a good substitute. Still more nearly to imitate the white cloud (in the day-time), it has been proposed to strew the mirror over with powdered marble or carbonate of soda, concentrating the rays of the sun upon it with a large condensing lens, or a surface of plaster of Paris has been proposed for the same end. In all cases where daylight can be employed, it is far superior to artificial light, and less injurious to the eyes. Bright sunlight should never be used, and any very strong light, either natural or artificial, is hurtful. If, however, proper precautions in this respect be observed, the general experience of microscopical observers shows that the moderate use of this instrument tends to strengthen, rather than to weaken, vision. Very often it will be desirable to shade objects as much as possible from all light, except that which is transmitted through them from the mirror. The diaphragm will effect this in part, and a black shade fixed perpendicularly on the stage is also useful. The eyes, too, should be protected from all light but that received through the microscope. If the eye-lashes are seen in looking through the eye-piece, the eye is too close, and you are looking on the eye-piece, not through it.

20. False light, or light reflected from any part of the

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* Mr. Smith in *Microscopic Journal*, vol. i.

mountings of the glasses, or from any part of the *interior* surface of the microscope, is a serious defect, as the glare and fog produced materially interfere with the clearness of the image: it is therefore quite necessary that the surfaces should be made as sombre as possible. Most microscopes now sent out are properly secured against such an evil, but if any prove defective in this respect, it may be remedied by heating the parts, and while hot covering them with a black lacquer, made by mixing lamp-black in a solution of shellac in spirits of wine. A still better plan is to wash over the parts (previously freed from grease and varnish) with a solution of platinum in nitromuriatic acid (chloride of platinum): after remaining on the work for a few minutes, it is wiped off, and the surface will be found to have assumed a deep-brown or black colour. *

21. A shade, either of glass, wood, or other convenient material, should be kept over the microscope when not actually in use, to preserve it from dust, and at the same time to avoid the necessity of taking it to pieces and packing it into its case. In cleaning the object and eye glasses, the best material that can be employed is a piece of soft chamois leather; it must be very gently used, so as not to disturb the setting of the lenses. It should always be remembered that in case an achromatic object-glass is made so as to separate into two or three pairs of lenses, which can be separately used, they must be screwed together again in the same order and position as at first: if the component glasses of any part are disarranged, they are useless.

22. It may be taken as a rule, that the *lower* the magnifying power is, which will satisfactorily exhibit the structure of an object, the better is the microscope. It is a great mistake to value an instrument by the number of times it will magnify. In a general way, the higher the power of a lens, the greater will be the difficulty of finding a minute object, the focus is far less easily adjusted, and the light is more faint and feeble. It is true that the improvements made in the construction of microscopes of late years have greatly obviated some of these difficulties; and so great have been the improvements in the lenses used, that many of low power of recent make will show more of the structure of a given object, than one of double the magnifying power would have done some years ago. A microscope with a lens of ¼-inch focus, which would clearly and distinctly show the lines on a particular scale, would be

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* Pritchard's *Microscopic Cabinet.*

vastly preferable to an instrument which required an ⅛-inch lens to exhibit the same lines as clearly. For those who use the microscope really for investigation, do not require the mite to be magnified to the size of an elephant, if thereby they gain no further information as to its structure. If *size* be the desideratum, a solar or oxyhydrogen microscope will be the one to please, for with these almost any amount of *magnifying power* can be obtained, though, at the same time, but little of *structure* can be seen.

But if *instruction* be sought, and *investigation* be the object, then a table microscope, such as we have been describing, even of the humblest class, is worth far more than the finest solar or oxyhydrogen instrument. The simple object of increased amplification is, or ought to be, to enable us to detect minutiæ of conformation, and thereby to aid us in the investigation of the structure and functions of the various forms of organic existence. These are the real uses of the microscope; these are the real objects of microscopic study; and in the pursuit of these will the student find sources of wonder and delight ever new and ever increasing, while *mere* magnifying power renders it only a toy, which, like all other toys, soon tires, and will be cast aside.

23. A word or two may be useful as to the finding of very minute objects for examination with high powers. It is a good plan to find the object with a low power, say ½ inch, and having adjusted the objects required to the exact centre of the field, carefully turn the milled head, so as to obtain a sufficient distance between the object-glass and the stage, to facilitate the removal of the former without in the slightest degree disturbing the slide. Now, attach to the microscope the power you desire to use, and by turning the milled head very gently and cautiously, bring it into focus, being scrupulously careful not by any jerk, &c., to move the object, even in the slightest degree. In this way there will seldom be any difficulty in viewing any object that may be desired, even with the highest powers.

CHAPTER IV.

MOUNTING OBJECTS.

24. Every one who uses a microscope desires to preserve many of the objects he examines in a permanent form for inspection at pleasure. This is termed "mounting" objects, and the following directions will enable any one with a little practice to accomplish this in a satisfactory manner. Whatever be the object intended to be mounted, good specimens, fully developed, and unmutilated, should be selected. They must also be perfectly clean, and free from dust or extraneous matter. Many objects may be cleared from such impurities, by the gentle use of a camel's-hair brush; others by washing in water, ether, or spirits of turpentine. Parts of insects, and small ones entire, when intended as transparent objects, may often be prepared for mounting, by being carefully laid out upon a slip of clean glass, and, when perfectly arranged, another slip of the same size and equally clean is laid gently over it, and the two bound together with twine. When the object is perfectly dry, the glasses are to be separated, and the preparation is ready for mounting. Various hints as to the treatment of particular objects will be given when we come to speak of them and to point out the method of obtaining them.

25. The object being selected, the *method* of mounting is the next thing to be decided on. There are four methods in general use, in each of which there are many variations in practice. These are, in Canada balsam; in fluids; dry; and as opaque objects. Those intended to be viewed by *transmitted* light, are mounted in one of the first three modes; those by *reflected* light in the last. We will suppose that the specimen selected is to be mounted as a transparent object: the question arises, which of the three modes shall be adopted. This must depend upon its character. Canada balsam possesses the highest refractive power, and therefore the most opaque objects are best suited for this medium, as it greatly increases their transparency. Various fluids are employed, where either the object would be altered in character or form if dried, or where more transparency is required than could

be attained without some medium, and where balsam would render them so transparent that their structure would be almost invisible. As a general rule, balsam is most suitable for sections of bone and horn, parts of insects (except scales and wings), dissections of crustacea and mollusca, sections of spines, fossil and recent infusoria (shelled), sections of wood, some kinds of pollen, petals, hairs, mosses, spores of ferns, and some few algæ and minute fungi. Objects most suitable for mounting in fluids are injected preparations, preserved infusoria, and minute crustacea, vessels of plants, cuticles of the same, leaves of mosses &c., and most algæ. Transparent objects mounted dry are sections of teeth (sometimes), feathers of birds, scales of fish, scales of insects, exuviæ and wings of the same, eyes of insects and crustacea, some kinds of pollen, hairs of plants, glands, starch, fossil woods (sections), some mosses, crystals for polarized light, and organic fabrics.

Opaque objects are usually minerals, seeds and leaves of plants, elytra of insects, minute shells, especially of foraminifera, shields of infusoria, &c. &c.

These lists may serve as general hints, but we shall point out more exactly what particular methods are required in speaking of the objects themselves.

26. Mounting in Canada balsam is a most valuable invention for the preservation of the less transparent class of objects, which, if suitable for transmitted light, it renders beautifully clear and transparent. We are indebted for its introduction to Mr. Pritchard. It has many advantages over other media. When once hardened it is permanent, unchanged by age, unaffected by damp, clear and transparent. One way of using it is as follows:—The slips of glass and balsam are to be warmed to a temperature little lower than that of boiling water. Then arrange the object on one of the slips, and pour over it a drop or two of the warm balsam. Then lay over it the upper slip, which is generally smaller than the under one, and of thin glass; one end of it should be brought into contact first, and the other then be allowed to fall upon it. In this way, if dexterously managed, a great variety of objects may be mounted without enclosing any air bubbles. These must be sedulously avoided, as they appear like black globes when viewed beneath the microscope, or, if large, very like black India-rubber rings. The proper quantity of balsam can only be learned by practice, but too much is decidedly better than too little.

27. Where the object is of such a nature as not to be injured by a moderate heat, the following plan is very successful, and easily managed:—A small portion of balsam is put upon a cleaned glass slide (if the balsam is old and thick, so much the better, if perfectly clear), and the object laid upon it; a slip of thin glass, about ½ inch square, is then laid over, and the slide is placed upon a warm plate of iron (the hob is a very convenient domestic substitute, provided the fire be small), or held over a spirit lamp till the balsam melts; the object looks transparent, and bubbles freely issue from under the thin glass. Now carefully press down the upper slip, so as to drive out the bubbles, and maintain a gentle pressure till the balsam cools, which will be in a minute or two at most. It may be expedited by blowing upon it. When animal structures, such as parts of insects, or injected preparations, have to be mounted, the heating of the balsam must be carefully managed, and the balsam itself be very fluid to commence with. It should be sufficiently warmed to expel all air-bubbles, and, when nearly cold, the object should be placed in it, and covered in the usual way. If the heat applied to the slide be great, the object will be sure to curl up, and bubbles will appear in all parts. It will be most likely rendered useless, as no manipulation, however carefully or skilfully applied, will restore an overheated specimen of animal structure to its former beauty.

28. For objects which do not require a magnifying power higher than an object glass of ⅓-inch focus, and which are of very cellular structure, such as sections of wood, leaves of mosses, some insects, and preparations from them, &c., a different plan may be adopted with advantage. Take two slips of glass of No. 2 size (see sect. 45), and (the upper glass at least) not exceeding 1/12 of an inch in thickness; clean them perfectly. Drop on one of them one or two drops of Canada balsam, and spread it; on the other, arrange the object for mounting in its desired position. Then bring the two slips into contact very carefully, so that the several edges are exactly adjusted, and press them together, so that they may have between them a film of balsam enclosing the object. Then tie them together with several turns of cotton thread, so as to prevent the glasses from slipping, fasten it by a knot, and, in cutting off, leave the ends three or four inches long. A small tin trough must be in readiness, slightly larger in size than the slide, and 1½ to 2 inches deep. Enough balsam, not old or thick, must be

poured into this trough, to cover the bottom to the depth of ¼ to ⅜ of an inch. Place the trough in an oven, with the slide laid level in the bottom, and the ends of the cotton hanging over the side. The oven should not be very hot, and one in a common range answers best. When the balsam is melted and quite fluid, and gives any indication of vapour rising from it, instantly transfer the trough to the plate of an air-pump, place the receiver on, and exhaust the air quickly. If the object be not tender (as sections of wood, &c.), this may be done as rapidly as possible; but if delicate, it must be done more slowly and cautiously. In most cases one exhaustion will be sufficient, in some few the operation may require to be repeated. After the air has been exhausted, it may rest for a few seconds; then re-admit the air, and having removed the trough from the plate, lift out the slide by the cotton ends, and lay it on a piece of paper till quite cold. The cotton and balsam on the exterior may then be scraped off by a knife, or, which is better, a strip of plate brass, and the slide finally cleaned up with a rag and spirits of turpentine, and then with a bit of wash leather, when, if the process has been properly performed, the object will be found beautifully embalmed between the two slips of glass, and perfectly free from air-bubbles. Where economy of time is any object, it will answer every purpose, after tying the slide up with cotton, to lay it on one side, and wait till a dozen or more objects similarly prepared have accumulated, and then finish the whole in the trough and air-pump one after the other. This will save much time.

29. A simpler modification of this plan, and applicable to the No. 1 size of slides (see sect. 45), is to mount the object in warm balsam, as detailed in sect. 26 (if a little more than ordinary is used, it will prove no disadvantage), press down the thin glass cover, place it on a warm metallic plate or block so as to preserve it in as fluid a state as possible; then place all under the receiver of a small air-pump, and exhaust the air. After remaining exhausted for a time, to allow the thorough escape of all air-bubbles, re-admit the air, when the superfluous balsam round the edges will sufficiently prevent its re-introduction. The employment of the air-pump will, however, be rendered in most cases unnecessary, by soaking the object for some time previously in spirit of turpentine. If very cellular, it might be placed beneath the air-pump, and the air exhausted while immersed in the turpentine. In all

cases where objects have been thus prepared, they should be transferred quickly from the turpentine to the balsam.

30. All objects should be thoroughly dried, and as completely as possible deprived of watery moisture, before mounting in balsam. Some vegetable objects and preparations, which are so delicate and transparent, that, when mounted in balsam, they become nearly, if not quite, invisible, can be successfully prepared in this medium by slightly charring them previously to mounting. To effect this, enclose the object dry between two slips of glass, tied together at either end with a thread, and hold them over the flame of a spirit lamp till it is sufficiently dark in colour, when it may be removed and mounted. When charring is inadmissible, it may be dyed in a solution of iodine, or a decoction of logwood. It will always be advisable (unless the balsam is very firm and old) to refrain from removing the superfluous balsam and cleaning up the slide for some time after the object is mounted. It should be kept in a warm room, or closet, for some weeks, to enable the balsam to become thoroughly hard and set.

31. Mounting in fluids must next claim notice. This mode of preparation is applicable to a variety of objects, which cannot be advantageously exhibited dry, and for which, from some cause or other, Canada balsam is not adapted. Both the fluids used, and the method of mounting require to be varied according to circumstances. We will first give the most approved formulas, and then point out their applications.

1. Cooper's Fluid.

Common Salt,	5 grains.
Water,	1 ounce.
Strong Acetic Acid,	5 drops.
Kreosote,	1 drop.

Mix well, then filter through filtering paper.

2. Solution of Glycerine.

Pure Glycerine,	½ ounce.
Water,	1 ounce.

Mix.

3. Goadby's Fluid.—(A 1.)

Bay Salt,	4 ounces.
Alum,	2 ounces.
Corrosive Sublimate,	2 grains.
Boiling Water,	1 quart.

Dissolve and filter.

4. Goadby's Fluid.—(A 2.)

Bay Salt,	2 ounces.
Alum,	1 ounce.
Corrosive Sublimate,	2 grains.
Boiling Water,	1 quart.

Dissolve and filter.

5. Goadby's Fluid.—(B.)

Bay Salt,	8 ounces.
Corrosive Sublimate,	2 grains.
Boiling Water,	1 quart.

Dissolve and filter.

6. Deane's Gelatine.

Pure Glycerine,	4 ounces.
Water,	2 ounces.
Gelatine,	1 ounce.

Dissolve the Gelatine in the water made hot, then add the Glycerine, and carefully mix.

7. THWAITES'S FLUID.

Distilled Water,	4 ounces.
Spirits of Wine,	½ ounce.

Kreosote, a few drops to saturate it. Stir in a small quantity of prepared chalk, and filter. With this fluid mix an equal quantity of camphor water, and before using, strain through a piece of fine linen.

8. SOLUTION OF CHLORIDE OF ZINC.

9. RALFS'S FLUID.

Bay Salt,	4 grains.
Alum,	4 grains.
Distilled Water,	4 ounces.

Dissolve and filter.

10. ARSENIOUS FLUID.

Saturated solution of Arsenious Acid,	1 part.
Distilled water,	2 parts.

Mix.

11. DEANE'S HONEY AND GELATINE.

Gelatine,	1 ounce.
Water,	5 ounces.

Soak till soft.

Honey,—5 ounces, heated by boiling in a water bath; mix it with the dissolved gelatine: boil them together, and, when somewhat cooled, add,

Kreosote, 6 drops, dissolved first in ½ ounce spirit of wine. Strain through fine flannel. To use it: first slightly warm the phial containing it; then drop a drop on a cleaned glass slide, previously warmed, and place the object in it. Then breathe on the thin glass cover, and apply it, taking special care to exclude air-bubbles; finally cement the edges with black japan, or one of the cements named below.

32. The above are the best fluids hitherto made known for mounting objects, though two (Nos. 6 and 11) can hardly be called fluids, as they are solid at ordinary temperatures. Cooper's fluid (No. 1) is specially adapted for preserving coloured vegetable tissues, such as the smaller fungi, &c. The glycerine solution (No. 2) is admirably adapted for most vegetable tissues, and it has the great recommendation of evaporating with great difficulty and slowness. It has very recently been stated (Griffith and Henfrey's *Micrographic Dictionary*) that fungi are apt to grow in dilute solutions of glycerine when used for mounting. If so, this is a serious drawback on its usefulness. Since the statement was published, however, the author has examined a series of slides of algæ, put up by him six or seven years ago, in solution of glycerine, and finds scarcely a trace of any parasitic growths. Perhaps it would be safer to use glycerine without dilution, or to dissolve in the water with which it is mixed, a few grains of corrosive sublimate.

33. Goadby's fluids (Nos. 3, 4, and 5), the solution of chloride of zinc, and the arsenious fluid (Nos. 8 and 9) are chiefly employed for animal structures. Goadby's fluid, A 2, (No. 4) is the most extensively useful; but in cases where great astringency is required to give form and support to delicate structures, Goadby's fluid, A 1 (No. 3), should be substituted. The mollusca, &c., however, contain carbonate of

lime, which decomposes the alum, forming sulphate of lime, which is precipitated, and the object spoiled. For such, the B fluid (No. 5) should be used; and in preserving marine animals, a still stronger solution (10 ounces to the quart) should be employed. The corrosive sublimate is intended to prevent the growth of confervæ in the liquid, which would otherwise soon spoil the preparation, but no greater quantity than that prescribed should be used. The chief objection to the saline fluids is, that very often the water gradually evaporates, even when confined by repeated layers of cement, and thus leaves the object free from fluid, but covered and surrounded by minute crystals of the salt. The cementing of the edges should, therefore, with these fluids especially, be most carefully attended to, and every precaution taken thoroughly to close all joints by repeated layers of the proper cement or varnish.

34. Chloroform has lately been proposed as a valuable antiseptic and preservative of animal substances, but its extreme volatility renders it very doubtful whether cells can be made completely impervious to it. Thwaites's and Ralfs's fluids (Nos. 7 and 9) are specially intended for mounting the minute algæ called Desmidieæ. Deane's gelatine (No. 6) is the author's favourite medium; it has the great advantage of setting firm almost immediately, and is not liable to evaporate or crystallize, as the saline liquids do, nor does it readily admit of the penetration of the cementing varnish beneath the upper glass. Fresh animal or vegetable structures require little or no preparation before mounting in it. Desmidieæ, crustacea, animalcules, &c., may be taken out of the water, placed on a slip of glass previously warmed, the superfluous moisture taken up by a torn edge of blotting paper, and then mounted at once by dropping a little of the medium upon them, and covering them with thin glass. As the gelatine sets to a firm solid at ordinary temperatures, it must be melted by a gentle heat previously to using, and both the glass slide and the thin glass cover must be made and kept warm during the operation of mounting. After it has become cold, the superfluous gelatine must be carefully cleared off, and the edges cemented with proper varnish.

35. Where the fluid solutions are employed, the following will be found one of the best methods of mounting with them. Prepare some slips of glass of either No. 1 or No. 2 size, by thoroughly cleaning them; rub them with a drop or two of

liquid ammonia and a morsel of tow to free them perfectly from grease, then wash in clean water and dry them thoroughly; next paint a circular ring or square (see fig. 7) on each of these slips, either with gold size, black japan varnish, or brunswick black, and place them in an oven to render the varnish perfectly hard. When quite hard and dry we may proceed to mounting. Lay the object in the cell formed, as above directed, with a small drop of the preserving fluid. The object should have been soaked for some time previously in the same fluid, or even in plain water, so that it may be thoroughly permeated by it, and contain no air-bubbles; and it should be quickly transferred from thence to its cell. Then lay over very carefully a piece of thin glass cut to a size slightly smaller than the outer margin of the cell, and press it down very lightly. The thin glass should be gently breathed on just before applying; and one end should be placed on the cell first, and then gradually lowered by a needle to its place, so as to drive air-bubbles before it. If there is any superfluous fluid it will now exude, and must be carefully taken up by torn edges of blotting paper, and the slide quite dried by repeated applications of the same material, special care being taken not in the least to disturb the position of the thin glass cover. These operations will require some delicacy of hand, which can only be attained by practice. Practice, too, will enable the operator to use just so much as, and no more than, is requisite to fill the cell.

36. The object is now mounted in its cell in a thin film of the preserving fluid, and protected with a glass cover. It must now be cemented, so as to prevent the evaporation of the contained liquid. Dip a small camel's-hair pencil in any of the following varnishes, as detailed below, Nos. 3, 4, 5, or 6 (sect. 39), and pass it round the edges of the thin glass cover, so as to form a thin bank of varnish connecting the cover with the slide. The slighter the film of varnish, in the first instance, the better; so that it connects the upper and lower glasses. When this is quite dry and firm, which will usually be in a few hours, a second coat may be applied; and especial care should be taken this time that the varnish is made to go just over the edge of the thin glass cover, so as to make the joint quite perfect. Three or four coats should thus be applied; and it is recommended by many to add a fresh coat once every six or twelve months, to make the joint perfectly secure. It will always be advisable, wherever sealing-wax varnish is used, not to

give more than one or two coats of it, but to let the remainder be of a more elastic and tough varnish, such as Nos. 1, 2, or 4.

37. For mounting crystals of salts, for viewing by polarized light, castor-oil is a good medium. Drop on a clean slider a drop of the warm solution of the salt to be mounted; and as soon as a good group of crystals has been obtained, draw off the supernatant mother liquor, by guiding it away with a wooden point. Set the slide up on end to dry, and when all moisture has perfectly evaporated, very carefully drop upon the crystals a drop of pure castor-oil, and guide it over the field with the point of a needle. Then place over it a cover of thin glass, lowering it gradually, so as to exclude every bubble of air. Finally, remove all superfluous oil with blotting paper, cleaning it off with special care, and cement the edges with two coats of sealing-wax varnish. When this is thoroughly hard, the slide should again be cleaned, so as to remove every trace of grease (should such remain) from around the varnish; then apply a third coat of sealing-wax varnish, and afterwards two of either Nos. 1, 2, or 4. None but sealing-wax varnish will answer for the first two or three coats.

38. Where deeper cells are required than those described in sect. 35 (as for injected anatomical preparations, &c.), thin transverse slices of glass tubes are very useful. The best way of cementing them to the glass slide is with marine glue. Thin small shavings of this may be laid on the slide, underneath the edges of the glass cell, and heat applied; the glue melts, and the cell, being pressed down, will adhere firmly to the slide. Superfluous portions of the cement may then be scraped away, and all traces finally removed from the glass by the careful application of solution of caustic potash. After the object has been placed in the cell, and fluid added to fill it exactly, a thin glass cover of the proper size is to be cemented on and the edge secured by a neat and narrow coat of varnish. Gutta percha cells are also easily made by cutting sections of a tube of that material. Heat alone is sufficient to effect their adhesion to the glass. Small square pieces of glass, with a hole drilled in the centre, also make very good cells; and large square cells may be made by cementing four narrow slips of glass to a slide, at right angles to each other, taking especial care that all the joints are made quite secure. Moulded glass cells are also now made, and sold at a reasonable rate.

39. We now proceed to give a list of the best cements for microscopic purposes. The hints already given, and the judgment and experience of the operator, will be the best guides as to which is most eligible for the object he may have in view.

1. Black Japan Varnish.

2. Japanner's Gold Size. Both these may be purchased of any chemist, and in the smallest quantities. They are best for the outermost coats of cement put on the edges of slides or cells containing preparations in fluid. If used for the first coat, they are very apt to penetrate, in course of time, beneath the thin glass cover, and so disfigure or spoil the preparation.

3. Asphaltum, dissolved in turpentine. If spirit is used as a preserving fluid, this answers. It possibly might for chloroform.

4. Gum Mastic and Caoutchouc, dissolved in chloroform, is an excellent cement, fluid at ordinary temperature, but rapidly becoming firm from the volatile nature of the chloroform. A mixture of this cement with the last is very suitable for fixing on the thin glass covers.

5. White Hard Spirit Varnish, thickened with lamp-black, is a good cement. It must be used promptly, as it soon gets hard. It must not be used as the *only* cement for objects in fluid, but must have a coat or two of black japan over it.

6. Black Sealing-wax Varnish. Break a small piece of best black sealing-wax into very small fragments; put it into a phial, and pour over it just enough spirits of wine to cover it. Set the phial in a gently-warm place, and shake it occasionally, now and then taking out the cork for a second. It will soon dissolve. It should always be shaken up before using. Red sealing-wax varnish may be prepared in a similar way.

7. Marine Glue is a mixture of shellac, caoutchouc, and naphtha. It is easily melted by heat. The kind most suited for microscopic purposes is known as G. K. 4.

8. Electrical Cement. 5 parts resin; 1 part bees'-wax; 2 parts Canada balsam; 1 part red ochre; 1 oz. of tallow, if necessary, all melted together.

9. Gutta Percha Cement, for making cells for dry objects; 1 part gutta percha dissolved in 15 parts spirit of turpentine; add 1 part finely-powdered shellac, and dissolve by heat and stirring.

A very useful and simple brass-cementing pencil has been described by Mr. Gorham, in the *Microscopical Journal.* It consists of a tube of brass, six inches long, with a conical bore, diminishing to a small aperture at the lower end. A few fragments of cement, made of 2 parts black rosin, 1 part bees'-wax, and 1 oz. vermilion, are dropped into the tube, which is then gently heated by a spirit-lamp till the cement begins to ooze from the small end. The melted cement is then traced along each side of the glass cover, the cementing pencil being held like a pen, leaving a line of cement in the angle.

40. We now come to objects mounted dry. For those which require a high power (¼-inch focus or less), the object must be laid upon a clean slip of glass (one with a cell of varnish, as described in sect. 35, is very useful), a cover of very thin glass laid upon it, and while this is kept in position by slight pressure, the edges are to be touched lightly with cement. Gold size, thickened with lamp-black, or the electrical cement (No. 8), or that described above as for the cementing pencil, are perhaps best. If gold size is used, it must be quite thick, however, or it will run between the glasses and spoil the object ; at the same time, the edges must be quite secured, so that neither air or damp can gain access to the object.

41. If, however, a lower power than ¼-inch be all that is needed, the following plan will be found a very neat and durable method of mounting :—A number of slips of glass, of the proper size (No. 2 is best), must first be bevelled at the edges. This may be done by procuring a piece of sandstone, such as is used for millstones ; and the upper surface being ground smooth, and water dropped upon it, the piece of glass is to be held on it at an angle of 45 degrees, and moved rapidly in that position backwards and forwards till the edge has become properly bevelled. If it is held by the fingers, care must be taken not to cut the fingers or their nails on the stone. Sometimes the glass is attached to a block of wood, one side of which is bevelled to the required angle. The glasses must be bevelled on all *four edges,* but of course only on one *side* of the glass. The stone which is employed for grinding on should be used equally all over the surface, or it will soon become uneven and cut the edges of the glass irregularly. It is well to have two similar pieces in use, and now and then to grind their surfaces together, so as to bring them to a perfect level. Cast-iron disks are sometimes used with emery and water, instead of sandstone or millstone. Care must be taken that the *surfaces* of the glass do not become

scratched; and, as soon as sufficiently bevelled, the sand should be rinsed off, and the slides wiped clean and dry. It will be found easiest and most convenient to have a considerable number of slides thus ground at once. The next step is to coat the bevelled edges with sealing-wax varnish. This may be made with the best red sealing-wax in the manner recommended for black sealing-wax varnish in § 39. To use it, warm the bottle containing the varnish by gently heating it before the fire; then shake it well up, and with a camel's-hair pencil dipped in it, paint the bevelled edges of the slides, and in half-an-hour or an hour they will be thoroughly dry. The varnish should be kept frequently shaken, as the red colouring matter is very heavy, and readily subsides. It will be found a great saving of time and trouble to prepare a considerable number of glasses in this way at once.

42. Now carefully lay the object to be mounted upon a slip of this glass (the inner side of the bevel), and over it lay another with the same face downwards, so that the two bevels form all around the edges of the slide a groove like the letter V (fig. 8). Hold the two slips in close contact by the fingers, so that the edges are exactly adjusted, and, with a spirit-lamp or gas-flame, slightly heat the groove at one end; then, with a stick of sealing-wax in the right hand, melt enough into the groove to fill it, and, as soon as that is cool, turn the slide, and fasten the other end in the same way. The slide is now firmly fixed, and as soon as it is cool, the side-grooves may be filled up in the same manner. Especial care must be taken in warming the grooves not to char or otherwise injure the object, and both object and glasses must be perfectly dry, else vapour will be generated, which will condense in minute drops as the glass cools, and quite spoil the slide. To give the slide a neat and finished appearance, it is necessary to clean off the superfluous wax. For this purpose lay a sheet of glass or sandpaper on a flat board, and rub the edges on it till quite smooth and level with the glass. They may now be again passed rapidly through the flame, which gives them a bright surface; and if any bubbles were formed in filling the grooves which the grinding has cut into holes, this melts them down and fills up all crevices. Slides *well* prepared in this manner are very durable. The labelling the slide is all that remains; and perhaps the best way of doing this is very neatly to write the name of the object on a small piece of paper, and insert it between the glasses at one end of the slide previously

to sealing. This method of mounting has, however, two drawbacks. It can only be conveniently used for No. 2 glasses; and unless great care be taken to prevent the accumulation of the least particle of moisture within the slide, and to secure the perfect dryness of the object and glasses, there will, in all probability, be a growth of minute confervæ all about the object, which will quite spoil it. The flame of the spirit-lamp might occasion a deposit of moisture between the glasses, if not carefully managed. We have seen numbers of otherwise well-prepared slides, which have become thus quite spoiled.

43. *Opaque Objects.* A great variety of methods have been proposed for mounting objects which are not viewed by transmitted light, but upon which the light must be condensed by a lens. Three only of these need be mentioned here; for they are so superior to the rest as to render the others well-nigh obsolete. Mahogany slides may be prepared of either No. 1 or No. 2 size, and about the same thickness as glass ones. A shallow cell, about ⅜-inch diameter, and $\frac{1}{16}$ deep, should be turned in the centre of each slide. If these are blackened inside, the objects may be fastened to the bottom of the cell by mucilage of tragacanth, also previously mixed with black. Dr Carpenter proposes a modification of this plan. He suggests that the slides should be *perforated* with a bore of ½ inch or so, and that a quantity of card-slips should be provided, of the same size precisely as the wooden slides. On the centre of each card-slip a piece of dead-black paper is next to be smoothly pasted; and the under surface of each wooden slide, being then wetted with paste or glue, is to be adjusted upon a prepared card, and kept under firm pressure till dry. The black paper, therefore, forms the bottom of the cell, and on it the object may be mounted as above. To preserve the object from dust, the slides may be kept face downwards, or they may be fastened together with an India-rubber band, or a cover of thin glass may be cemented over the orifice of the cell.

44. But the neatest method of mounting opaque objects hitherto designed is one for which we are indebted to Mr. Quekett. A small phial cork is to be cut to the proper length, with a perfectly level top, and is then to be fastened by any cement inside a small pill-box. (See fig. 9.) The upper surface of the cork should be slightly below the upper edge of the box when open. The cork and inside of the box should

be coloured dead-black. The object is to be fastened by any cement on the upper surface of the cork, and the name written on the lid of the box outside. The boxes used by chemists, and called "1 Drachm Purple-shouldered Boxes," are the neatest and most durable kind, and may be had at a cheap rate. The author has adopted a modification of this plan, for mounting fragments of flint enclosing fossil remains (corals, sponges, spirulinæ, &c.), when intended as opaque objects. The box is nearly to be filled with a putty made of whiting, boiled oil, and lamp-black. In this the fragment of flint is imbedded, and the surface intended to be viewed properly adjusted. The putty soon becomes hard, and makes an excellent mounting. For placing these opaque boxes on the stage of the microscope, a slide of mahogany, with a shallow cell cut in it of the proper size to contain the box, and about ⅛-inch deep, is very convenient.

45. *Glass Slides.* Various sizes have been used for the purpose of mounting objects upon; but, by common consent they seem to be reduced in practice to two, which are all that are necessary. The first size, which we shall call No. 1, is 3 inches long, by 1 inch broad. This is now considered the standard size, having been adopted as such by the Microscopical Society of London. The second is 2 inches long, by ⅝ of an inch wide; this we call No. 2, and has some advantages over the last. It is much more convenient for the two processes previously described, in which two pieces of glass of equal size are used to form the slide; while the much smaller space which they occupy in a cabinet will be to many an additional recommendation. Perhaps the best plan is to adopt both sizes, selecting the size to be used according to the nature of the object and the mode of mounting.

46. The glass to be used must be selected carefully. It should be free from veins and bubbles. Each piece should be viewed along the edge, and the palest alone selected. Those which are of a light blue or pale green are the best. Dark pieces should be rejected. The next thing to be done is to provide yourself with suitable gauges. There must be two for each size of slides, and they may be made of planed pieces of mahogany or birch, and should be from 6 to 12 inches in length, and ¼-inch thick. For No. 1 slides, one must be $2\frac{\text{[illegible]}}{16}$ inches wide, and the other $\frac{\text{[illegible]}}{16}$ of an inch wide. For No. 2 slides, the one must be $1\frac{\text{[illegible]}}{16}$ inches wide, and the other $\frac{\text{[illegible]}}{16}$ of an inch wide. A cutting-board must also be

provided; it may be made of deal, 1 foot long, and 8 or 10 inches wide, and properly squared. It should have a raised edge at one end, about ½ an inch above the level of the board. Now cut one side of your piece of glass straight; place it on the board with its cut side close to the raised edge; then take the broader gauge for whichever size of slide you wish to cut, and place it upon the glass, also close to the raised edge, and with the diamond cut the glass by the gauge. It will be a strip corresponding in *width* to the *length* of the slides to be cut. The cut strip may now be shifted a little over the edge of the board, so that one end may be cut off square. This done, place the strip at right angles to its former position, its squared end resting close to the raised edge. Now take the narrower gauge for the same size of slide, and lay it also over the glass and close to the flange, and cut off a strip. Break it off, push the glass up to the top again, and with the gauge and diamond cut another, and so on till a sufficient number are obtained. Unless, however, you are in possession of a diamond, it will often be found an easier and more economical plan to employ a glazier to cut up a considerable quantity at once, guiding him by the directions just given, than to purchase one. If, however, the latter is determined on, great caution should be exercised in its use, as by an improper mode of cutting, it is easily spoiled. It is better, in this case, to observe a practised glazier, and to gain a little instruction from him before making the trial yourself.

47. It is always well, even if the slides are not to be bevelled, to grind off the sharp edges of the strips on sandstone with water before they are used for mounting. It gives them a much neater appearance, and prevents their wounding the fingers, or cutting the paper with which they are sometimes covered. After the object is mounted, and the slide cleaned up, it requires to be labelled, for ready selection and recognition afterwards. It may appear superfluous to say anything about so very simple a matter; but there are two very neat plans in use, which to some may be worth mentioning. Some microscopists are in the habit of labelling their slides by writing the name of the object at one end with a *writing diamond.* This is a very durable and indelible mode of marking them, and occasions no trouble. A writing diamond may be purchased for about 8s. Slides thus marked are not, however, so readily legible as by the following.

Another, and a very neat plan, is to cover the slide with some figured glazed paper, *e.g.*, purple and gold, or green and gold. Slips of this paper should be prepared about $\frac{3}{16}$ of an inch larger every way than the slide to be covered, and with two holes punched in them—one for the object to be seen through, the other near one end, as a place for the label. Then paste the cover, taking care to let it lie till the paper has become soaked and perfectly flaccid; then, having previously pasted a piece of good writing-paper over one end, lay on the cover, being careful that the object is brought into the centre of the punched hole, and that the label-hole comes over the writing-paper, and fold the sides over the edges of the slide. Another slip, a trifle smaller every way than the slide, and with a hole in the centre to correspond exactly with that on the upper slip, is now to be similarly prepared, and pasted on the back; and the name being now written on the label, the slide is finished. For the No. 1 slides, a very neat figured paper may be purchased of Mr. Pritchard, 162, Fleet Street, being an engine-turned gold pattern on dark purple paper, designed especially for slides, and with blank spaces for punching out.

48. *Cabinets.* Almost every microscopist has his own preferences in this respect; but some, especially beginners, may be glad of a hint or two as to the best methods of arranging and preserving slides. One method, for a small collection, is to have a cabinet with shallow drawers (12 of them occupy a depth of 4¼ inches), the most convenient width from front to back being 6 inches. Into these shallow drawers the slides containing the objects are laid flat in double rows. The outer ends of the slides are made to fit into a ledge in the front and back of each drawer. The inner ends of the slides, meeting in the middle of the drawer, are kept down by a slip of wood covered with velvet. In this way, the slides do not shake when the cabinet is moved from place to place; every object is seen without removal, and thus no loss of time is occasioned in the selection. Of course, the dimensions given may be varied at pleasure, according to the number of slides the cabinet is intended to contain. Another very useful mode, especially for No. 2 slides, is to prepare trays thus:—A piece of good and thoroughly-seasoned mahogany, ¼ inch thick, and measuring 8¼ by 9 inches, is to be clamped at the two ends across the grain, by ½-inch pieces of the same wood, rising ¼ inch above the surface. The two sides may be of plate brass rising the same height. By means of three strips of

mahogany, 8¼ inches long, ⅛ wide, and 1/12 inch thick, glued on the tray, is divided into four compartments, each a trifle more than 2 inches wide. A coveris then made of mahogany, about ⅛ of an inch thick, clamped at both ends across the grain, which fits within the tray, and is fastened by four buttons, screwed on the ends of the tray. This will contain 44 slides of No. 2 size; and a cabinet can be adapted to contain any number of such trays that may be desired. It will be well to have the front and lid of the cabinet both hinged after the manner of a music-case, so that the former may fall down when it is unlocked and opened.

49. For opaque objects, a different arrangement is required; but it is not often necessary to have a separate cabinet, as a drawer or tray may often be adapted in depth and divisions especially for them. If Mr Quekett's pill-box plan be the one adopted, a drawer, with proper partitions, to keep the boxes in rows, will be advisable. For slides of No. 1 size, especially where they have frequently to be moved from place to place, boxes or drawers are commonly adopted, 3¼ inches in clear width, or containing partitions of that width, and 1 inch deep. Along each side of the box or of the partitions are then glued thin slips of wood, similar in length and depth, with perpendicular grooves, about ⅛ inch deep, and ¼ inch apart. The grooves on opposite sides of the box or partition, must exactly correspond to one another. The slides are then slipped in edgeways, each end resting in a groove.

50. A list of the most useful matters for a student of the microscope to have in readiness may now be given, and will conclude this part of the subject:—

Glass Slides, edged, No. 1 size.
Do. do., No. 2 size.
Do. bevelled, No. 2 size, and edged with sealing-wax varnish.
Thin glass, in squares and circles, thickness about 1-30th of an inch.
Slips of paper (punched), for covering slides.
Spirits of turpentine.
Black Japan varnish.
Sealing-wax varnish, red and black.
Deane's glycerine.
Canada balsam.
Marine glue.
Muriatic acid.
Nitric acid
Camel's-hair brushes.
Very fine pointed scissors.
Pill-boxes (1 drachm), purple-shouldered.
A fine file.
Piece of washleather.
Glycerine.
Needles in handles.

CHAPTER V.

OBJECTS.—THE VEGETABLE KINGDOM.

51. We now proceed to describe some of the most interesting objects which the microscope reveals to us; and we propose, in doing so, to take them in a connected order, so that the beginner may not only have some idea of what to look for, where to find it, and what to see, but that he may also be guided to some information with regard to each object he examines, as to its place in the system of nature, and have some clue to the many facts which may probably be known respecting its history and structure; for we cannot consider the microscope as a mere toy; but even though taken up for amusement, as being the delightful guide, if its possessor will use it rightly, to large acquisitions of most interesting and important knowledge. He who has made the most extensive acquirements in natural science will esteem the microscope to be his right-hand friend; while, to the beginner, it is most important as being an invaluable aid to investigation, and at the same time a most delightful recreation.

52. We begin, then, with the vegetable kingdom. Plants, however minute or large, are composed of what is termed elementary tissue, which exists either as membrane or fibre; of these, every part of every tree or plant, however varied in form or appearance, is composed. This elementary tissue takes various forms; of these, *cellular tissue* is the most universal. This is a constituent of every vegetable, and sometimes comprises their entire mass. Its proper form is that of little bladders or cells, which of themselves are globular or oval, but by close pressure together, assume a 12-sided figure (6-sided in section). Very thin sections of cellular tissue are beautiful objects for the microscope, appearing like the most regular and delicate network. Some of the most interesting are the following:—

Sect.—Elder pith.
,, Leaf stalk of papyrus.
,, Leaf of white lily.
,, Various species of Juncus (rush). Fig. 28.
,, Stem of bean (*Vicia faba*).

Sect.—Stem of sweet flag (*Acorus calamus*).
,, Banana (*Musa*).
,, Young petiole of Bur reed (*Sparganium ramosum*).
,, Adult do. do. do.

53. The rushes, banana, sparganium, and bean have curiously-branched cells; that of the *Acorus calamus* is also very curious. The mode of cutting these sections will be explained when speaking of wood (sects. 78-80). A very beautiful variety of cellular tissue is that called "Fibro-cellular" (fig. 12), which consists of a spiral fibre coiled inside a cell. This is well seen in the *Sphagnum*, a moss which grows commonly in large tufts on spongy bogs, and a small sprig of which, with three or four leaves clearly displayed, forms a most beautiful object mounted dry. It must be thoroughly pressed and dried between blotting-paper for some days before mounting, as it retains moisture very tenaciously, and if mounted at all damp will soon spoil. Another variety of this tissue is found in the seed-coats of *Collomia linearis*, *Collomia grandifolia*, *Acanthodium spicatum*, *Maurandya*, and several species of *Salvia*. This is a beautiful sight, under a low power (1 inch or ½ inch) of the microscope. Lay a glass slip on the stage of the microscope, and bring the lens into focus for its upper surface. Then pare off with a penknife a minute slice of the seed-coat, lay it on the slide in the field of view, and put over it a small drop of water. See that it is properly in focus, and watch it. The seed is covered with these cells, the membrane of which is gelatinous and very soluble, so that, as the water softens it, and it dissolves, the fibres uncoil, exhibiting a beautiful and interesting phenomenon.

54. *Woody fibre* is another form of the vessels of plants. It consists of transparent, tough, spindle-shaped tubes, tapering at each end. It is this kind of vessel which forms the chief part of all wood, and which gives it its tenacity and firmness. The fibres of flax and hemp will be the easiest attainable examples of woody fibre in a separate state, and may be mounted dry. Linen, therefore, is formed from woody fibre. Cotton, on the other hand, consists of elongated cells or hairs, the membrane of which becomes contracted in the process of drying, so as to appear twisted when viewed under the microscope. By this character, the cloth in which the ancient Egyptians enveloped their mummies has been shown to be linen. Every tree or shrub exhibits this kind of vessel; but in order to show its character well, the sections should be longitudinal (in the direction of the stem's growth), not transverse. A curious variety of this tissue is found in the trees composing the natural order *Coniferæ*

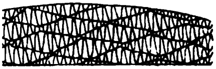


Fig. 12.

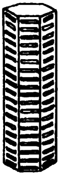


Fig. 13.

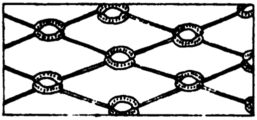


Fig. 14.

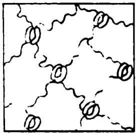


Fig. 15.

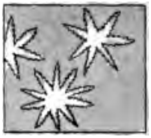


Fig. 16.

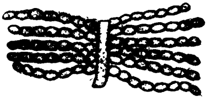


Fig. 17.

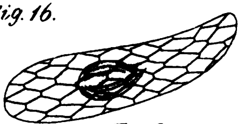


Fig. 20.

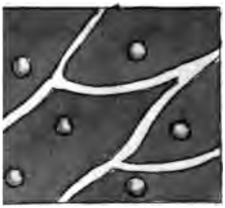


Fig. 18.

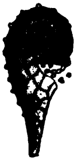


Fig. 21.

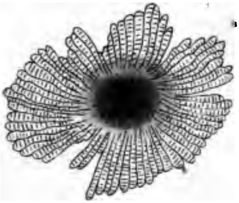


Fig. 22.

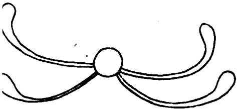


Fig. 19.

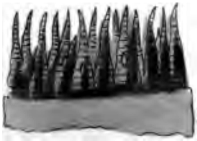


Fig. 23.

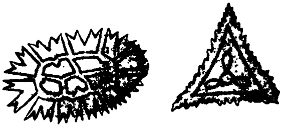


Fig. 24.

(containing the pine, larch, fir, yew, cedar, juniper, &c.) The woody fibre of these trees appears to be glandular. When examined by the microscope, they are found to have minute circular disks arranged at short distances through the length of each vessel. These are very well seen in a very thin deal shaving, or any other longitudinal sections of the wood of coniferous trees. In Araucaria (the Norfolk Island and Chili pines) and Altingia, the rows of glands are double or triple.

55. *Spiral vessels* are elongated tubes clustered together, within the membrane of which a spiral fibre is coiled throughout their whole length. To mount them as objects it is advisable to have them entire, and it is therefore desirable to dissect them from out the other vegetable matter in which they are contained. This may be done with the assistance of the single microscope, or with one of the compound ones with a low-power lens, the body being removed, or *with* the body including the erector. A lens of 1-inch or 1½-inch focus will answer well. A stem of asparagus is one of the best and most easily accessible sources of good specimens of spiral vessels. Having cut a piece an inch long, split from it, by a sharp knife, a very thin piece; fix one end of the slice to a slip of glass on the bottom of the dissecting tray (sect. 3), with bees'-wax, and dropping a little water upon it, proceed with a long needle or two, or with needles in handles, to separate the vessels from the cellular tissue in which they are imbedded. A little practice will render this easy. If the vessels selected are not to be mounted speedily, they should be kept in a little spirit of wine till required. They are also found in the white water-lily (*Nymphæa alba*), in liliaceous plants, in the gourd, in the leaf-stalk of the garden rhubarb, the India-rubber plant, the leaf-stalk of the strawberry, &c., &c. Thin vertical sections of the yew, and of *Araucaria excelsa*, exhibit the peculiar glandular dots of the *Coniferæ* with spiral vessels. Branching spiral vessels are also found in the mistletoe and long-leek.

56. *Ducts.* Annular ducts are vessels something like the last, but the internal fibre is in separate rings, and not in one continuous coil. *Reticulated vessels* have two sets of internal fibres crossing one another. Sometimes the fibre is so broken into fragments that the vessel appears dotted with fragmentary lines of unequal size. *Scalariform vessels* (fig. 13) (from *scala*, a ladder) have the fibre arranged in transverse lines at nearly equal distances, like the steps of a ladder. Annular ducts are

obtainable in plenty, and in variety of form, from the stem o the garden balsam, and reticulated vessels from the commo carrot. Scalariform vessels are obtained in great beauty fro the vine, or from many ferns, such as the brake (*Pteris aquilina*) the royal fern (*Osmunda regalis*) &c., &c.

57. *Porous vessels* are of large size, and are so called fro the porous or dotted appearance of their surface. They ar comparatively short, and are united to each other, end to end by a partition or septum. The garden balsam, the vine traveller's joy (*Clematis vitalba*), sugar-cane, gourd, bamboo stems of *Arundo donax*, or any large grass, &c., afford goo sources whence to dissect these vessels. The foregoing ar the chief forms of the elementary tissues of plants, and a collection of these, made from any of the sources indicated, wil possess great interest, as well as afford very beautiful an elegant objects; and will also be a source of most valuabl instruction and information, in studying the various structure which the vegetable world displays.

58. The next subject which claims our attention is the contents of cells. In many plants the cellular tissue is found t be stored with a variety of substances, some of which we ma appropriately notice. In certain cells a deposit of hard, woody or stony matter, goes on during the growth of the plant, til sometimes the cell is quite filled up with these foreign matters which are deposited in regular layers, and will appear, o cutting a section, like a series of concentric circles, or i stellate or various other forms. The following will be som of the most interesting objects of this class. Thin section must be used.

Shell of the Cocoa-nut.
Coquilla, or Cocos-nut. (This is the fruit of a Palm.)
Shell of Brazil-nut.
,, Hazel-nut.
,, Vegetable Ivory nut. (*Phytelephas macrocarpa*.)
Testa of seed of Star anise. (*Illicium anisatum.*)
Stone of Apricot.
,, Plum.
,, Damson.
,, Peach.
,, Tamarind.
,, Date.
,, Cherry.
Some cells in the pulp of the Pear.

59. The method of making sections of these is as follows:— Cement by a little Canada balsam a small piece of any on of them to a slip of glass, and with a fine file, cut away th upper surface to a perfect level: then the filed surface is t be ground perfectly smooth upon a hone, and finally polishe with putty powder and a piece of wash leather. Now, war the slide, so as to melt the balsam, and loosen the object, o

soak it in ether for the same end; spread on a perfectly clean slide, on which it is intended to be finally mounted, a drop of clear balsam, and place the object in it with the polished side downwards. Now warm it till the balsam would become hard in cooling, and press the cut object firmly to the slide till the cement sets. The side which was formerly the cemented one, being now uppermost, is in its turn to be pared, filed, and ground, till the preparation is reduced to a film so thin that its structure can readily be discerned on wetting it with a drop of spirit of turpentine and viewing it through the microscope; then polish it as before. The dirty and superfluous balsam, dust, &c., is now to be carefully cleared away with a pen-knife, and finally with a little spirit of turpentine. Then pour on the section a drop of clear balsam, lay over it a piece of thin glass, and mount it as an object as directed in sect. 26. Sections of the subjects mentioned above will be found well to repay the trouble of cutting, and will be varied and interesting in their appearance, while they are very easily accessible. Most of them will need a lens of high power, and some an achromatic, to make them out well.

60. *Starch.* This is another deposit commonly occurring in cells, as may readily be seen by any one who, with a razor, will take off an extremely thin slice from the inside of a potato. On submitting it to the microscope, it will be seen to be composed of hexagonal cells of considerable size, each enclosing a number of minute oval or pear-shaped bodies. These are granules of starch. Magnified by an achromatic lens of pretty good power, their surface appears to be encircled with a series of rings, proceeding from a central point, which is called the *hilum.* These starch-granules have a very important function to perform in the economy of the plant. They exist in a greater or less quantity in nearly all vegetables, and appear to be nutritive matter stored up by the plant in its cells for the supply of its future wants and growth. Starch is gum, slightly altered, and contained in a series of minute bags, for the purpose of removing it out of the action of the circulating fluid. It appears to be destined especially to assist in the nourishment of the young parts, for, when these are growing, the store of starch rapidly diminishes. Grains of starch are composed of a membrane, evidently composed of numerous layers, enclosing a soluble matter within. If heated in water to 160°, the membrane bursts, and its gummy con-

tents are set free, and dissolve in the water. Viewed l microscope, grains of starch differ greatly in size and a ance, according to the plant by which they are produ thus affording a very simple and excellent means of dete the adulterations so prevalent in many articles of food.

61. The largest are those of *Tous-les-mois* (the starc *Canna coccinea*), which is used as an article of food ; the n in size are those of potato-starch, which are very irregular shape. This starch is often used for adulterating arrow-ro and is sometimes entirely substituted for it. East In arrow-root (starch of various species of turmeric, *Curcuma*) nearly equal in size, but very different in appearance, to th last. The next in size are those of West Indian arrow-roo from *Maranta arundinacea* (this is the genuine article o commerce); sago (which consists of numerous grains of starch collected into little balls); sago-meal, from India (the produce of a kind of date-palm); and plantain-meal (starch of a Musa). The smallest kinds are starch grains of Tapioca, starch grains from wheat, barley, oats, rye, maize, or Indian corn, and the Tahiti or missionary arrow-root. The minutest of all are those of the root of *Arum maculatum* (our wild arum), and of rice. Curious club-shaped starch grains are found in *Euphorbia splendens.* It is not to be supposed that the above are all the varieties of starch that are obtainable; but they are the most interesting yet observed, and being very easily accessible, are well worth the investigation of the microscopist.

62. The examination of these will also be important and valuable, on account of its bearing upon the adulteration of common articles of food. A caution must hence be given to obtain genuine samples, those sold in the shops, especially by grocers, being often largely sophisticated. In Dr. Royle's *Materia Medica*, 2d edition, pp. 683, 684, are a series of figures of the principal starches of commerce, which will be a guide to the verification of the specimens. Genuine samples being obtained, their microscopic comparison with a suspected sample will at once prove its genuineness or adulteration; and besides, if sophisticated, will reveal the nature and proportion of the admixture. In examining unknown specimens, should any doubt exist as to whether any particular granules are starch, it may be at once decided by allowing them to come in contact with a minute drop of weak tincture of iodine, when, if starch, they will at once assume an intense

blue colour. Starches should be mounted dry; but it is well to place between the slips of glass a piece of thin dark-coloured paper, with a hole punched in the centre for the object, to prevent pressure, which, if the glasses are perfectly flat, might otherwise injure the specimen. Under the polarizing apparatus, many starches exhibit the beautiful phenomenon of the black cross.

63. *Raphides.* These are crystals which abound in the cells of some plants. From the needle-like appearance of the most abundant kinds, the name Raphides (Greek, *raphis*, a needle) has been given. Raphides are either separate or in clusters, the former being commonest. Separate raphides may be seen by cutting across any liliaceous plant, as the hyacinth, onion, garlic, lily, &c., and spreading a little of the juice very thinly upon a glass-slide; on submitting it to the microscope, the needle-shaped crystals will be seen among the juice. To obtain them for permanently mounting, the juice or portion of the plant should be digested in a solution of caustic potash; in some cases it may be used hot. After the vegetable matter is dissolved, repeated washings with boiling water will thoroughly cleanse the crystals. A caution here, however, is necessary (and it is equally applicable in regard to all minute objects which have to be thus washed in preparation for mounting). A sufficient time must be allowed for the crystals completely to settle at the bottom of the vessel in which they are contained, before the supernatant liquid is poured off, as otherwise the most beautiful of the objects may be thrown away with the rejected water. Raphides may be mounted dry, or in Canada balsam, if they are to be viewed by polarized light.

64. The following plants will afford some of the most interesting examples:—

Aloe—various species.
Cactus—various species.
Wing of the seed of common Elm.
Calyx of Clove Pink.
Calyx of Carnation.
Bark of Lime (Tilia).
Apple Tree.
Squill.
Hyacinth.
Tulip.
Onion.
Grape Vine.
Hickory.
Fuchsia.

The following will afford specimens of clustered raphides:—

Root of Rhubarb, especially Turkey Rhubarb.
Calyx of various Pelargoniums (greenhouse geraniums).
Various malvaceous plants (Mallow, Hollyhock, Althæa, &c.)
Calyx of Geranium Robertianum.
Calyx of Geranium lucidum.
Calyx of Strawberry
Beet.
India-rubber Plant.

The preceding are the chief cell deposits of interest to the microscopist.

65. The next vegetable structures which will demand our attention are the compound organs. Most plants, though ultimately composed of cells and vessels, are nevertheless made up of various organs or parts, which are usually recognisable by the unassisted eye, and are covered with an epidermis or skin. These are distinguished into *nutritive* and *reproductive* organs; the former are the root, stem, and leaves; the latter are the flowers and fruit.

The epidermis or skin, and its appendages, will first come under our notice. This is a thin layer of (generally) flattened cells, which covers every part of the plant which is exposed to the air, except the stigma. The epidermis presents great variety of appearances in different plants. Sometimes the lines which bound the cells are straight, sometimes wavy and curved; and here and there they are interrupted by oval orifices, which are called *stomata* (figs. 14, 15), (Greek, *stoma*, a mouth). These stomata are the breathing pores of the plant, and from their functions possess great interest. On examination with an achromatic lens of high power, the stomata are found to consist of two semi-lunar cells, surrounding an oval slit or orifice, which have been compared to the lips and orifice of the mouth. These lips open and close, according to the state of dryness in the atmosphere. Stomata are not found in roots or in cryptogamic plants, nor on those which grow beneath the surface of water, with a few exceptions. In most instances, they are much more abundant on the under surface of leaves than the upper, where they are very often entirely wanting,—a beautiful provision of the Great Creator for defending these breathing pores from dust or dirt. They are much more abundant on leaves than on any other part of the plant. Cuticles with their stomata are easily separated after a short maceration in water, during which the water should not be changed. A few drops of nitric acid added to the water will assist in detaching them. Very thick leaves may require boiling. From some they can be obtained by raising a small piece with the edge of a pen-knife, and then suddenly and dexterously stripping it off. Large pieces may be thus obtained from *Yucca gloriosa* and others.

66. The following list will be found to embrace the most curious and interesting varieties of cuticles and stomata known. For many of them, as for some of the subsequent lists, we are

indebted to Mr. Pritchard's *Microscopic Objects.* In order to facilitate their acquisition as far as possible, the common names have been added. A leaf of many of the foreign species may be obtained readily from a nurseryman. Most of the British species are accessible to all.

CUTICLES AND STOMATA OF BRITISH PLANTS.

Hedera helix; common ivy.
Poa trivialis; meadow grass.
Tamus communis; black bryony.
Marchantia polymorpha; liverwort.
Primula vulgaris; primrose.
Iris pseudacorus; yellow flag.
Ribes rubrum; red currant.
Ligustrum vulgare; privet.
Rumex acetosa; sheep's sorrel.
Viola canina; dog's violet.
Viola odorata; sweet violet.
Helleborus fœtidus; bear's-foot.
Ranunculus aquatilis; white water crowfoot.
Dianthus caryophyllus; clove pink.
Cuticle of the columella of capsule of Funaria hygrometrica,—a very beautiful object.

CUTICLES AND STOMATA.—FOREIGN PLANTS.

Hydrangea.
Yucca gloriosa; Adam's needle
Zea mays; Indian corn.
Nerium Oleander; oleander.
Syringa vulgaris; lilac.
Begonia.
Hoya carnosa.
Aucuba Japonica; aucuba.
Cactus opuntia; cochineal plant.
Agave Americana; great American aloe.
Lilium candidum; white lily.
Caladium esculentum.
Crinum amabile.
Gardenia latifolia.
Vicia faba; bean.
Iris Germanica. (Fig. 14.)
Iberis umbellata; candy tuft.
Cocos nucifera; cocoa-nut palm.
Aloe viscosa.
Rubia tinctorum; madder.
Saxifraga sarmentosa.

The above will generally require to be mounted in fluid.

67. The following cuticles are very beautiful objects prepared in the following manner:—Boil any of the following in strong nitric acid in a tall vessel; copious fumes will be given off as the carbon is being removed. The vessel should be then laid aside for a time, and more acid added, when the effervescence has ceased. If the specimen be not immediately wanted, it may be kept in the acid till the perfect removal of all the other constituents has been effected. It may be mounted, when thoroughly washed, either in balsam, in fluid, or dry. In fluid, its structure is best shown. In balsam, it is an admirable object for polarizing. The paleæ (chaff scales) of *Festuca pratensis* (meadow fescue-grass), are very beautiful, either as opaque objects, or as transparent ones mounted in fluid.

Equisetum hyemale (Dutch rush).
Wheat.
Wheat straw.
Barley.
Barley straw.
Oat.
Oat straw.
Canary seed (husk).
Canary straw.
Cuticle of Pharus cristatus.

Cuticle of Deutzia scabra.
Husk of rice.
Rye.
Rye straw.
Malacca cane.
Manilla cane.
Dragon "
Wanghae "
Bamboo "
Rattan "

One of the most splendid cuticles for the microscope is of the petals of many of the greenhouse geraniums (P goniums), especially the darker coloured varieties. Inman directs the cuticle to be peeled off from the petal making an incision through it at the end of the petal, a then tearing it forward. Arrange the cuticle on a slip glass, and let it dry. Place on it a little Canada balsa diluted with turpentine, and boil it for an instant over th spirit-lamp; then cover it with a piece of thin glass, t preserve it.

68. *Appendages to the Epidermis* are hairs and scales, and glands. Simple as these may appear, they will be found to be very various and curiously modified, both as to form and colour. They are composed of one or more elongated cells, and proceed from the epidermis. Hairs may be either simple, forked, branched, beaded like a necklace, or composed of several elongated cells; they may be composed of many branches, radiating from a centre, like the arms of a star-fish (stellate hairs), or they may exist as flat, shield-shaped scales; or they may assume a brown, chaffy appearance (called *ramenta*), as the scales on many ferns. The hairs from the pod of the cowhage (*Mucuna pruriens*) are used in medicine as a vermifuge; under the microscope, they appear like porcupine quills, and are worth mounting. A very common hair is that attached to the seed of the cotton-grass (*Eriophorum angustifolium*). It appears like a long ribbon, with a great number of joints. The cotton-grass is a common plant on our bogs and moors, adorning them about May and June with its white silky plumes. These, as well as those on the following lists, marked with an asterisk, may be mounted dry; the rest either in fluid or balsam. Small pieces of the leaves of those given under the head Scales, and of *Durio zibethinus* and *Deutzia scabra*, make interesting opaque objects for low powers. The hairs of *Deutzia*, *Durio*, *Dolichos*, *Elæagnus angustifolia*, and the Olive, may also be treated with nitric acid, as described in the last section. A search among the hairs of all plants to which the observer can get access, will scarcely fail to reward him with other specimens of interest and beauty.

FORKED AND BRANCHED HAIRS.

* Arabis alpina.
* Mathiola incana; stock. B.
* Sisymbrium sophia. B.
* Verbascum Thapsus; mullein. B.
Humulus Lupulus. B.

BEADED AND CELLED HAIRS.

Delphinium pinnatifidum.
Lychnis chalcedonica; scarlet lychnis.
Bryonia alba.
Nicandra anomala.
Borago officinalis. B.
Anchusa tinctoria.
—— crispa.
—— angustifolia.
Anagallis arvensis (pimpernel). B. (Fig. 17.) Hairs on stamen.
Symphytum asperrimum.

SCALES.

* Hippophae rhamnoides. B.
* Shepherdia argentea.
* Elæagnus angustifolia.

STELLATE HAIRS.

* Althæa rosea.
Durio zibethinus.
Deutzia scabra. (Fig. 16.)
—— gracilis
Alyssum calycinum.
Viburnum opulus. B.
Corræa speciosa (petal).

RAMENTA.

Lastræa Filix-Mas; male fern. B.
—— dilatata. B.
—— cristata. B.
Polystichum lobatum. } (Prickly ferns.) B.
—— angulare.
—— lonchitis.
Polypodium vulgare; polypody. B.
Scolopendrium vulgare; hart's tongue. B.
Ceterach officinarum; scaly hart's tongue. B.

Those marked B above are wild British plants.

69. *Glands.* This name is applied to any collection of cells forming *secretions*, which are products separated or elaborated from the juices of the plant, apparently serving no purpose of nutrition, and never (so far as we know) converted into the materials of its tissues. These glands assume very various forms. Some are stalked, standing on the tip of a hair of greater or less length. On the flower stalk of the garden snapdragon (*Antirrhinum majus*), numerous glandular hairs will be found, consisting of hairs formed of several cells surmounted by a roundish or pea-shaped secreting cell. A similar hair, surmounted by a two-celled gland, may be found in the common loose-strife (*Lysimachia vulgaris*). A very common plant, the avens (*Geum urbanum*), has a gland of several secreting cells, surmounting a hair. The following common English plants have also glandular hairs, which may be examined with interest:—

Sagina apetala.
Arenaria rubra; red sand-wort. (Calyx and flower-stalks.)
Hypericum hirsutum; hairy St. John's wort. (Calyx.)
—— elodes; marsh do. do. do.
Linaria vulgaris; common toad flax. (Flower-stalks.)
Geranium pratense; meadow crane's-bill. (Capsule.)
Rubus (many varieties); blackberry. (Stem, leaf-stalks, flowering panicle.)
Sonchus arvensis; corn sow-thistle. (Calyx and flower-stalks.)
Cerastium glomeratum; mouse-ear chickweed.
Anagallis arvensis; pimpernel. (Fringing the petals.)

Drosera longifolia ;
—— rotundifolia ;
—— anglica ; } **sundew. (Leaves.)**

A portion of the leaf, with the glandular hairs of the three last, forms a ve nice object.

70. The next kind of glands we have to notice are thos commonly called stings, of which the two common British nettles afford most familiar examples. In these, the secreting cells are at the *base* of the hair, which is itself hollow, serving as a tube through which the fluid secreted by the gland is discharged. The stiff hair having pierced the skin, the same pressure which has caused its entrance, forces up the fluid contained in the secreting cell into the wound, and occasions the pain and inflammation. The stings of some of the tropical species of nettle, as *Urtica urentissima*, a native of Timor, and *Urtica crenulata*, are so virulent as to occasion serious illness, and even death. The following plants afford some of the best examples :—

Urtica dioica ; common nettle.
—— urens ; small do.
—— pilulifera ; Roman do.
and various foreign species of nettles.
Loasa, various species.
Malpighia fucata.

Malpighia urens.
—— cubensis.
—— angustifolia.
—— aquifolia.
—— macrophylla.

The stinging hairs of Malpighia will be found chiefly under the leaf.

71. Sessile glands next come under notice. These are sometimes composed of cells enclosing a secreting cell, forming a kind of globe on the surface of the leaf, &c. ; or of cells surrounding a cavity in the leaf itself. In some of these latter kinds the leaf is covered with down or hair, which will require to be shaved off before the glands can be well seen. They are generally situated on the under side of the leaf, and can only be mounted as opaque objects, but as such many of the following (especially in a fresh state) are very beautiful, resembling rubies, emeralds, &c., set in a dull dark ground.

SESSILE GLANDS.

Dictamnus albus ; fraxinella.
Rosa centifolia ; cabbage rose.
—— rubiginosa ; sweet briar.
Mesembryanthemum crystallinum ; ice plant.
Cicer arietinum ; chick pea.
Lastræa oreopteris ; heath polypody.
Humulus Lupulus.
Helistropium Europæum.

GLANDULAR CELLS.

Hypericum perforatum ; common St. John's wort.

Ruta graveolens ; rue.
Mentha (various species) ; mint.
Origanum onites ; pot marjoram, (fig. 18.)
Aloysia citriodora ; lemon plant.
Salvia (various species) ; sage.
Ribes nigrum ; black currant.
Thymus vulgaris.
Calamintha officinalis.
Betonica officinalis.

A thin section of the albumen of the cocoa-nut, shows a collection of soft walled cells with abundance of oil in their cavities.

72. *Stem.* Next to the cuticle and its appendages comes the stem. To enter upon the detail of its structure in a physiological point of view would occupy much too large a portion of our space: we can only point out a few particulars as specially instructive to the microscopical student. All stems are composed of vascular and cellular tissue (vessels and cells) variously arranged, and may be classed either as *exogens*, *endogens*, or *acrogens*. To understand at all the facts which microscopic sections of stems can teach us, it is necessary that these terms be understood, as they are at the foundation of the natural classification. *Exogenous stems* (fig. 27), in their most perfect state, are composed of three distinct portions, viz., pith, wood, and bark. The pith is a mass of cellular tissue, occupying the centre of the stem, although in old branches or trees it often entirely disappears. Plenty of examples of it may be obtained: one, however, is very curious. *Rice paper* is nothing else than the pith of a shrub (*Æschynomene aspera*) cut very thin in a spiral manner, as if a sheet of paper were unrolled from a round ruler. Magnified by a low power, its cellular structure is beautifully seen. In the walnut and jessamine the pith is broken up into regular cavities. Outside the pith is the wood. It is formed in layers, the inner part of which consists of vessels or ducts, and the outer of woody fibre. One layer is formed every year outside that of the previous one, and between it and the bark, the woody fibre being chiefly deposited towards the close of the season. The trunk is thus continually increasing in diameter, and from this mode of growth, derives its name *exogenous* (from *exo*, outwards, and *gennao*, I produce—Greek). It will be evident, therefore, that, as every year a new layer is formed, the inner part of which is chiefly ducts, &c., or larger vessels, and the outer woody fibres, which are smaller, that a horizontal section would readily show the age of the trunk or branch by the number of rings it contains; and this is a principle of almost universal application.

73. In the herbaceous exogens, and in trees in their earliest growth, the woody fibre appears as a series of plates or wedge-shaped bundles, radiating from the large central pith to the external bark. They are separated by a continuation of the pith. This structure is very beautifully shown in a horizontal section of the purple clematis. When a second ring is formed, the woody plates approximate much closer to each other, till at last the prolongations of the pith form merely lines radiat-

ing from the centre to the circumference. These prolongati of the pith are, like it, formed of cellular tissue, and a called *medullary rays*. They are known to carpenters as t *silver grain*.

74. The bark is composed of three layers. The inner bar or *liber* is chiefly composed of woody fibre and vessels. Thi part of the bark of the lime-tree is used to make mats, cordage and sacking. The liber of the lace-bark tree (*Lagetta lintearia*) is the natural lace of the West Indies. In the lime, oak, ash, and *Daphne laureola*, it forms a similar network. The middle bark is composed of cells, often three, or many-sided. In the outer bark the cells are usually cubical, or four-sided. Sometimes it consists of only a single layer of cells, or occasionally is of great thickness. The bark of *Quercus suber* (cork), and the corky bark of the maple (*Acer campestre*), are examples of this latter.

75. *Endogens* (fig. 26) present a very different structure. In these there is neither true bark, nor pith, nor concentric circles of growth. The stem does not increase by additions made to its exterior, but in its interior, and hence the name *endogen* (*endon*, within; and *gennao*, I produce—Greek). The stem is a mass of cellular tissue, with bundles of vascular tissue (woody fibre, &c.) scattered throughout its extent. The fibres connected with the leaves are directed towards the centre of the trunk, and pass downwards towards the root. After a time they bend outwards towards the circumference; so that in the lower part of an old trunk this comes to be a densely-packed and matted mass of woody fibres, and is often so hard as to resist the blow of a hatchet: the centre being soft and cellular, with the woody bundles interspersed. Endogenous trunks increase in *diameter* but little after they have attained a certain size, so that while exogens may increase to an almost unlimited amount, endogens are soon stopped by the density of the outer part of the stem.

76. *Acrogens* form the last of the three divisions, under one or other of which all plants may be arranged. When these have regular stems, they will be found to be composed of a circle of vascular tissue, situated near the circumference; the centre of the stem being either hollow or cellular. The circle of vascular tissue is broken up into masses of irregular shape and size, which, nevertheless, in the aggregate, form a circular band. These vascular masses or bundles are composed of woody fibre on the outside, within which scalariform, annular,

and porous vessels (sects. 56, 57), make up the remainder of the mass. The growth is always upward or onward, never in an expansive direction, and additional *vessels* are always formed *simultaneously* with the addition of cellular tissue, not progressively increasing as in the last two orders. From this mode of growth the name is derived (*acros*, summit, and *gennao*, I produce), indicating that the increase is *onwards* from the growing point. They have, therefore, no concentric circles, nor any true bark.

77. These various characters, and their modifications in the different species, are well seen in vertical and horizontal sections. These are full of interest and beauty, and are of almost endless variety. We will now, therefore, give directions as to the best modes of cutting and preparing sections, and then append an arranged list of the most interesting examples hitherto noticed. First, then, as to cutting sections. For perfect specimens, three sections should be taken of each exogenous stem, viz., one *horizontal*, and two *vertical;* one of these being parallel to the medullary rays, and the other at right angles with them. Of endogens and acrogens, one vertical and one horizontal section are sufficient. The two or three, as the case may be, should, if possible, be mounted on the same slide. They may be mounted either dry, or in balsam, as directed in sects. 26-28. This latter, however, is only admissible for horizontal sections.

78. One of the best machines for cutting sections is that represented in fig. 10: "*a b* is a flat piece of mahogany 7 inches long, and 4 inches wide, to the under surface of which is attached, at right angles, a piece, *g*, of the same size as *a b;* *d* represents a flat plate of steel, 4 inches long and 3 inches wide, screwed to the upper surface of *a b*. To the middle of this plate is attached a tube of the same metal, *e i*, 3 inches long, and ½ an inch diameter, and provided at its lower end with a screw, working in a nut, and having a piston, *k*, exactly adapted to the bore of the tube. This piston is connected with the upper end of the screw, and is capable of being moved up and down by it. *c* is another screw connected with a curved piece of brass, *h*, which is capable of being carried to the other side of the tube by it. The piece of wood intended to be cut is put into the tube *e*, and being first wedged in tight, either having been cut to the proper size, or, if too small, fixed by screwing *c* firmly against it, is then raised by turning the lower screw, so that the thinnest possible slice may be taken

off by the knife (*f*). The slices should be immediately dr ped into spirit and water, in which they may be kept till it convenient to mount them. The knife used may be one co structed for the purpose, or a good razor ground flat on on side will answer very well. The lower part of the instrument *g*, is intended to enable it to be fastened to a bench, or clump may be provided to screw it to a table, in which case the projection, *g*, may be dispensed with." It is probable that the first few sections will have to be rejected on account of being too thick, but practice and patience will overcome this difficulty. Both horizontal and vertical sections should exhibit but one layer of cells, and therefore be perfectly transparent. The price of this, or a similar instrument, is usually about £1, 11s. 6d.

79. The following simple little apparatus will, however, answer in most cases equally well, and has the advantage of being made at the cost of a shilling or two. It is, we believe, the invention of Mr. A. Nicholson of Fareham. Procure a small block of seasoned mahogany, 2 inches wide, 2 inches thick, and 3 inches long. A V-shaped groove must be cut in it (as in fig. 11, *a*), reaching nearly to the bottom, and of equal size throughout; a wall about a half inch thick being left at one end of the block. The sides of this groove must be quite smooth. In the back a brass-plate should be let in, in which a fine-threaded screw, about $2\frac{1}{8}$ inches long (*b*) works, with a milled head on its outer end. The screw should be fixed so that its inner end is about $\frac{1}{8}$ of an inch from the bottom of the groove and perfectly parallel therewith. The bottom of the groove is better not sharp, but rounded, and about $\frac{1}{10}$ of an inch wide. To cut a section of wood (if a twig or small stick, not exceeding $\frac{1}{4}$ to $\frac{3}{8}$ of an inch diameter; if larger, a small [illegible]be, or cylinder, which is preferable, about $\frac{3}{8}$ inch thick, and [illegible] inches long, may be cut from it and used), lay a piece 2 to $2\frac{1}{2}$ inches long, and squared at each end, into the groove, one end resting against the screw, hold the block in the left hand, the fingers resting on the portion to be cut, to keep it firm and steady, then turn the screw till it projects from the front of the block in the least possible degree, and with a sharp razor, ground flat on one side, and grasped firmly in the right hand, cut a section, guiding its edge along the face of the block. After a few trials it will be found easy to cut sections with only one layer of cells. For vertical sections cubes of wood must be pre-

viously cut in the required direction, so that the side presented to the edge of the razor may be the section required. It may be an improvement on the above to screw a plate of steel on the front, or cutting face of the instrument.

80. A third method is to bore a large gimlet or small auger hole in the flat side of a piece of deal; into this drive the piece of wood of which sections are desired, and, if needful, wedge it tight with small pieces of deal. Then having with a chisel cut it off level, with a sharp plane take off very thin shavings of the deal, and the wood to be cut will be sliced with the same cut: a few shavings thus made, with care, will generally be found to furnish one or two very tolerable sections.

Some precautions are required in cutting woods. If the wood be hard, and contains resin of any kind, or gum, it must first be digested in some liquid, which will dissolve the resinous or gummy matter. Spirit of turpentine or naphtha will commonly answer, but sometimes mineral naphtha, ether, or some other solvent may be required. When perfectly freed from these matters it is ready to be cut. Some recommend that woods should be perfectly dried before being cut; others that they should be fresh, or well soaked in water previously; we have generally found the latter preferable. The cutting instrument should be very sharp, so as to avoid breaking or tearing any of the vessels in making the section.

81. For the larger part of the following lists of plants from which to obtain the most instructive and interesting sections, we are mainly indebted to Mr. Pritchard's *Microscopic Objects*. To facilitate their study and acquisition we have classified them, and have given, as far as possible, both the scientific and common names, so that the plant intended may be readily known. Many of the foreign ones are common in gardens, shrubberies, or nurseries, and are, therefore, easily accessible; others, curious for their peculiar structure, are not often to be attained, yet well worth mounting, when accessible.

EXOGENS. BRITISH PLANTS.

Agrimonia Eupatoria; agrimony.
Alnus glutinosa; alder.
Althæa officinalis; marsh-mallow.
Angelica sylvestris; angelica.
Pyrus malus: apple.
—— communis; pear.
Fraxinus excelsior; ash.
Populus tremula; aspen.
—— nigra; black poplar.
Fagus sylvatica; beech.
Betula alba; birch.
Menyanthes trifoliata; buckbean.
Arctium Lappa; burdock.
Brassica oleracea; cabbage.

Brassica napus; turnip.
Chenopodium (various species); goose-foot.
Centaurea nigra; knapweed.
Prunus cerasus; cherry.
—— avium; black cherry.
—— domestica; plum.
—— spinosa; blackthorn.
Castanea vulgaris; chesnut.
Clematis vitalba; traveller's joy.
Cornus sanguinea; cornel.
Rumex sanguineus; red dock.
—— acetosa; sorrel.
—— hydrolapathum; water dock.
Sambucus nigra; elder.
Ulmus campestris; elm.
Eryngium maritimum; eryngo.
Fœniculum vulgare; fennel.
Corylus avellana; hazel.
Ribes grossularia; gooseberry.
Viburnum opulus; guelder rose.
—— lantana; wayfaring tree.
Conium maculatum; hemlock.
Ilex aquifolium; holly.
Hedera helix; ivy.
Tilia Europæa; lime.
Malva sylvestris; mallow.
Acer campestre; maple.
—— pseudo-platanus; sycamore.
Mespilus germanica; medlar.
Aconitum Napellus; monkshood.
Artemisia vulgaris; mugwort.
—— absinthium; wormwood.
Sinapis arvensis; charlock.
Solanum nigrum; nightshade.
Quercus robur; } oak.
—— sessiliflora; } oak.
Pastinaca sativa; parsnip.
Petroselinum sativum; parsley.
Rubus idæus; raspberry.
Rosa canina; dog-rose.
Ligustrum vulgare; privet.
Salix (various species); willow.
Daucus carota; carrot.
Carduus nutans; musk-thistle.
Taxus baccata; yew.

EXOGENS. FOREIGN PLANTS.

Acacia catechu.
—— fragrans.
Acrocomia aculeata.
Amaranthus caudatus; love lies bleeding.
Amaranthus hypochondriacus; Prince's feather.
Armeniaca vulgaris; apricot.
Cynara Scolymus; artichoke.
—— carduncculus; cardoon.
Banksia (various species).
Laurus nobilis; bay.
Cerasus Lusitanica; Portuguese laurel.
—— laurocerasus; laurel.
Begonia discolor; begonia.
Encephalartos; Caffre bread-tree.
Artocarpus incisa; bread-fruit.
—— integrifolia; jack tree.
Cactus (various species).
Casuarina quadrivalvis; she-oak.
Æsculus Hippocastanum; horse-chesnut.
Callistephus; China aster.
Chrysanthemum sinense; chrysanthemum.
Cinnamomum zeylanicum; cinnamon.
Cissampelos Pareira; Pareira brava.
Clematis cerulea; purple clematis.
Quercus Suber; cork.
—— infectoria; gall-oak.
Cycas revoluta.
—— circinalis.
Dahlia variabilis; garden dahlia.
Euonymus tingens.
Ficus Carica; fig.
Morus tinctoria; fustic.
—— nigra; mulberry.
Helianthus annuus; sunflower.
—— tuberosus; Jerusalem artichoke.
Juglans alba; hickory.
—— regia; walnut.
Althæa rosea; hollyhock.
Magnolia grandiflora.
Swietenia mahogani; mahogany.
Atropa Mandragora; mandrake.
Mangifera indica; mango.
Nepenthes distillatoria; pitcher plant.
Solanum Melongena; egg plant.
—— tuberosum; potato.
Platanus orientalis; plane.
Rheum palmatum (petiole); rhubarb.
Cucurbita Pepo; gourd.
Rhus typhinus; sumach.
Tectona grandis; teak.
Tamarindus indica; tamarind.
Nicotiana Tabacum; tobacco.
Liriodendron tulipifera; tulip tree.
Vitis vinifera; vine.
Ipomœa turpethum; turpeth.
Wintera aromatica.

The following Exogens belong to the order Coniferæ, and exhibit the glandular woody fibre (§ 67).

Salisburia adiantifolia.
Pinus Deodara; deodara.
—— Strobus; Weymouth pine.
—— cedrus; cedar of Lebanon.
Araucaria excelsa; Norfolk Island pine.
—— spiralis.

Cupressus thyoides; American cypress.
Thuja orientalis; arbor-vitæ.
Juniperus Virginiana; red cedar.
Callitris (various species).
Abies (various species); fir.

The following Exogens present curious and remarkable variations from the ordinary structure; and are therefore anomalous. They are all foreign.

Gnetum.
Calycanthus floridus.
Paullinia pinnata
Serjania triternata.
Bignonia capreolata.
Heteropterys anomala.
Aspidospermum excelsum.
Phytocrene.
Banisteria nigrescens.

ENDOGENS. BRITISH PLANTS.

Typha latifolia; reedmace.
Scirpus palustris; bulrush.
Iris pseudacorus; yellow flag.
Acorus calamus; sweet flag.
Ruscus aculeatus; butcher's broom.
Convallaria polygonatum; Solomon's seal.
Juncus effusus; } rush.
—— maritimus; }

ENDOGENS. FOREIGN PLANTS.

Agave Americana.
Bambusa arundinacea; bamboo.
Bromelia ananas; pine apple.
Zea mays; Indian corn.
Crinum amabile.
Epidendrum elongatum.
Furcrea vivipara.
Aloe (various species). (Flower-stalk)
Allium porrum; leek. (Flower-stalk.)
Doryanthes excelsa.
Peristeria alata.
Saccharum officinarum; sugar-cane.
Smilax aspera; sarsaparilla.
Uvularia Chinensis.
Yucca gloriosa; Adam's needle.

The following are Palms, and are very beautiful examples of Endogenous structure, though not very frequently accessible in this country.

Areca triandra.
Calamus (various species); canes.
Chamædorea gracilis.
Chamærops elegans.
Cocos nucifera; cocoa-nut.
Corypha australis.
Phœnix dactylifera; date-palm, (leaf stalk.)
Phœnix paludosa
Oreodoxa regia.
Phytelephas macrocarpa; vegetable ivory palm.
Corypha umbraculifera; talipat palm.
Latania borbonica.
Sagus Rumphii.

ACROGENS. BRITISH PLANTS.

Osmunda regalis; royal fern.
Pteris aquilina: brake.
Lastræa Filix-Mas; male fern.
—— dilatata.

FOREIGN.

Todea africana.
Tree ferns.

Sections of the following *roots* are interesting.

EXOGENS.

Quercus robur; oak.
Fagus sylvatica; beech.
Callistephus; China aster.
Chenopodium album: goosefoot.
Leontodon taraxacum; dandelion.
Corylus avellana; hazel.
Carpinus Betulus; hornbeam.
Armoracia rusticana; horse-radish.
Urtica dioica; nettle.
Phytolacca decandra.
Juniperus Sabina; Savin.
Dipsacus sylvestris; teazle.
Vitis vinifera; vine.

ENDOGEN.

Aloe (various species).

82. *Fossil woods* present objects of great interest, inasmuch as they show the identity of the structure of the most ancient trees and plants of our earth with those which now abound around us. They prove to us that the primeval forests of our globe, which rose, flourished, and decayed countless ages before man trode its surface, were yet composed of exogens, endogens, and acrogens, as our present ones are, though the *species* which

then abounded have long since passed out of existence. Of all the multitudes of plants which crowded the forests of the Carboniferous, the Oölitic, the Wealden, or the Chalk eras, not one now exists otherwise than in a fossil state; and strange, as well as beautiful, must have been the forms of many of these, as their remains reveal them to us. It would be useless to give a list of the most interesting kinds, as, of course, they are not to be met with easily like the recent ones given above; but it will always be worth while to make a section of such pieces of fossil wood as are attainable, and at least in two directions,—perpendicular to the grain, and parallel with it. If an exogen, *three* sections should be cut as in recent woods of the same kind. Coal, and the vegetable remains which occur in company with it, afford many most interesting examples of fossil vegetable structure, proving beyond a question its vegetable origin. Jet and anthracite, too, often afford beautiful specimens. Much of the coal appears to have been formed of vegetable matter, which, before its conversion into a bituminous substance, had already, to a great extent, undergone decomposition, and, therefore, most frequently, coal only exhibits *traces* of vegetable structure; but often very perfect specimens may be obtained exhibiting the vascular and cellular tissue most completely.

83. To prepare these sections, it is obvious a very different process must be adopted from that given for recent woods. The best mode is to cut a thin slice by a lapidary's wheel. As, however, few persons possess this apparatus, a good substitute may be made for it by any one who has a lathe. If a thin circular plate of soft iron be fixed upon an axle, so fitted as to be very rapidly turned by the multiplying wheel of the lathe, with its lower edge passing through a trough containing emery and water, it will readily cut through a fossil presented to its edge, and in this way a slice may be cut off. It must then be cemented on a glass slide with Canada balsam, the upper side ground smooth with emery and water, and then polished with putty powder and leather. This is best done by means of a couple of horizontal wheels, one of lead for the emery and water, and a wooden one covered with leather for polishing. They should be made to revolve with great rapidity by means of a multiplying wheel. When polished, the cement is to be loosened by heat, and the *polished side* cemented to a glass slide, when the process is to be repeated on the side now uppermost, taking care to grind it down to

a film sufficiently thin, clearly to display the structure of the wood. Coal, anthracite, and jet, must be ground down to a mere film. In the manner now detailed, any fossil woods may be cut in sections, and their structure beautifully exhibited by transmitted light. In a general way, the section will require no further mounting after being ground and polished as directed above.

84. A novel process has, however, been recently published for cutting thin slices of coal for the microscope. Macerate small pieces of coal in a strong solution of carbonate of potass for about seven days; it will then be found possible to cut thin slices by a razor. Place these slices in a watch-glass, and pour over them strong nitric acid sufficient to cover them; then gently heat by a spirit-lamp: they will soon turn brownish, then yellow. Immediately the process has reached this point, arrest it by dropping the whole into a saucer of cold water. The slices, having been thoroughly washed, will be of a dark amber colour, very transparent, and will admirably exhibit the vegetable structure. They are to be mounted in glycerine.

85. Although a *list* of *fossil woods* would be useless to the microscopic student as an aid in the obtainal and selection of objects, it may be of some service to point out some localities where they may be obtained with more or less facility. In some coal-mines whole stems are occasionally found, which are sure to afford exquisite sections. The principal English coal-fields are in Northumberland, Lancashire, Yorkshire, Derbyshire, Leicestershire, Warwickshire, Bristol, and North and South Wales. Throughout the strata of the secondary formations, which, with the exception of the counties of Norfolk, Suffolk, Essex, Lincoln, Cornwall, Devon, and Cumberland, occupy almost all England, fossil woods are frequently found imbedded in the rock, sands, or clays, and may be cut in sections. In the quarries of the Isle of Portland, there is a bed called the Dirt-bed, in which fossil trunks and branches of trees, and stems of a cycas or zamia-like plant are found. At Lulworth Cove, in Dorsetshire, and on the coast of the Isle of Wight, at Brook Point, numbers of fossil trunks are found. In the former they are still in position as they grew, and at the latter spot, embedded in the clay cliff and in the rock, and also in abundance on the beach. In Bedfordshire, Dorsetshire, and near Hastings, fossil-wood and beds of wood-coal (wood partially carbonized) are often found in the iron-sand.

In the cliffs on many parts of the coast of Yorkshire, vegetable remains, fossil trunks and wood, and wood-coal abound; and in the cliffs of London clay in the Isle of Sheppey, vast numbers of fossil fruits, and portions of wood belonging to many species of trees, are commonly found. This list, very imperfect as it is, must suffice as a hint here. For more detailed information on this point we refer the inquirer to Mantell's *Medals of Creation*, and Lindley and Hutton's *Fossil Flora*.

86. We come now to the reproductive organs, the flower and the fruit. The flower, in its most perfect state, is composed of calyx and corolla, which are called the *floral envelope*, and of stamens, pistil, and germen, which constitute the true reproductive organs. The calyx seldom affords any microscopic objects other than hairs and glands, which have already been noticed. Some few petals make beautiful objects, dried between sheets of blotting-paper under pressure, and then mounted in Canada balsam, applying just sufficient heat to cause the balsam thoroughly to penetrate the cells of the petal, and to exclude all air-bubbles, and yet not enough to discharge or destroy the colouring matter, upon which the chief beauty of the object depends. The petals of *Anagallis arvensis* (pimpernel or scarlet chickweed), various *Pelargoniums* (greenhouse geraniums), especially the deeper coloured ones, and *Corræa speciosa*, are very beautiful objects; or they may be prepared by immersing the petal in ether for a few seconds, allowing the fluid to evaporate, and then put up dry. Many other petals will doubtless be found to reward investigation.

87. Within the circle of the petals are found the *stamens*, which in most plants form a ring or whorl around the germen, but in some they are found occupying separate and distinct flowers. The stamen consists usually of a thread-shaped stem (or *filament*) supporting a more or less oval or globular body called the *anther*, which consists of lobes or cavities filled with a powdery matter denominated *pollen*. The membrane lining the interior of the anther is formed of a layer or layers of cells with a spiral, annular, or reticulated fibre within them. Those of the following will repay examination.

Wallflower.
Saxifraga umbrosa.
Daisy.
Lupinus nanus.
Cereus speciosus.

88. The pollen is well worthy of careful investigation, as it affords a great variety of beautiful microscopic specimens.

The subjoined lists contain some of the most remarkable kinds. They may be mounted in Canada balsam, or, if rather transparent, in fluid, or dry. Generally they make interesting opaque objects. Very beautiful opaque objects for low powers may be prepared by picking anthers of any of the following plants soon after they have opened, while yet much pollen remains undischarged, and before they have begun to wither; lay the anthers flat between two pieces of blotting-paper, and dry them under moderate pressure; then mount as directed for opaque objects.

WILD ENGLISH PLANTS: FOR POLLEN.

Anagallis arvensis; pimpernel.
Campanula trachelium; Canterbury bell.
Arbutus unedo; strawberry tree.
Circæa lutetiana; enchanter's nightshade.
Trifolium pratense; clover.
Digitalis purpurea; foxglove.
Œnothera biennis; evening primrose.
Geranium sanguineum.
Delphinium consolida; larkspur.
Tilia Europæa; lime.
Urtica dioica; nettle.
Papaver somniferum; white poppy.
Saponaria officinalis; soapwort.
Sedum acre; wall pepper.
Viola tricolor; heart's ease.
Stratiotes aloides; water soldier.
Lythrum salicaria; willow herb.
Cichorium intybus; endive or chicory.
Lilium martagon; Guernsey lily.
Verbascum blattaria; moth-mullein.
Symphytum officinale; comfrey.
Armeria maritima; thrift.
Tulipa sylvestris; tulip.
Fragaria vesca; strawberry.
Pæonia corallina; pæony.
Epilobium montanum; willow herb.
Sonchus palustris; marsh sow-thistle.
Sherardia arvensis; field madder.

FOREIGN AND GARDEN PLANTS: FOR POLLEN.

Acacia lophantha.
—— laxa.
Calla Æthiopica.
Cineraria maritima.
Ipomœa (various species).
Coreopsis lanceolatus.
Elymus sabulosus.
Iris (various species).
Fuchsia coccinea; common fuchsia.
—— globosa.
Lilium tigrinum; tiger lily.
Tagetes; African marigold.
Periploca græca.
Inga anomala.
Passiflora (various species); passion-flower.
Cucurbita Pepo; gourd.
Scorzonera hispida.
Erica multiflora.
Ruellia formosa.
Hibiscus trionum.
Mimulus moschatus.
Heracleum sibiricum.
Althæa rosea; hollyhock.
Iresine diffusa.
Jasminum.
Lupinus (various species); lupin.
Lychnis flos Jovis.
—— chalcedonica; scarlet lychnis.
Malope trifida.
—— grandiflora.
Mirabilis; marvel of Peru.
Reseda odorata; mignonette.
Citrus aurantium; orange.
Pancratium declinatum.
Polygonum.
Salvia interrupta.
Scirpus mucronatus.
Solanum dulce.
Helianthemum; sunflower.

89. There is no question but that the use of the pollen is to fertilize the ovules or young seeds. For this purpose the pollen, or some of it, must fall on the terminal portion of the

pistil called the *stigma*. After lodging here for a certain time it sends forth tubes of extreme fineness, formed by a prolongation of the internal membrane of the pollen grain. These tubes pass down the centre of the stigma, which is a partially hollow space, so constructed as to receive these tubes; and thus the liquid matter occupying the interior of the pollen grain is conveyed to the young seeds. This fertilizes them, and without this they would never arrive at perfection. To see this beautiful operation as it actually takes place in the stigma, involves dissection of the utmost delicacy and accuracy, such as few can hope to attain; but any one may observe the emission of the pollen tube, and its office in conveying the liquid contents of the grain, by immersing a few particles of the pollen of *Datura Stramonium* (thorn-apple) in a drop of very dilute sulphuric acid on a glass slide, and observing them with a lens of considerable power.

90. Seeds will also claim a brief notice from us. Most commonly they come to perfection enclosed in a seed-vessel of very various form. Those seeds which are of chief interest as microscopic objects, are generally mounted as opaques; a few, however, may be mounted dry or in balsam as transparent objects. The seeds of various species of Orchidaceæ are very beautiful; mounted dry or in balsam, they resemble a net-purse, enclosing a golden ball. Several seeds, too, have a membranous border or ring, which is often very interesting when detached from the seed and mounted in balsam. *Lophospermum scandens* and some others afford specimens of this kind. *Alsine marina*, a common plant on our shores, has a similar seed, which may be mounted dry. The seeds of *Galinsogea parviflora* are surrounded by a ring of minute leaflets, forming a pretty little stellate group. The seeds of some species of *Salvia*, *Collomia*, and *Acanthodium*, have spiral fibres covering them, which, when immersed in water, uncoil, exhibiting a very pretty spectacle. (See sect. 53.)

SEEDS: BRITISH WILD PLANTS.

Senecio vulgaris; groundsel.
Hypericum quadrangulum; square stalked St. John's wort.
Papaver somniferum; white poppy.
Stellaria holostea; stitchwort
Euphorbia peplus; petty spurge.
—— Portlandica; Portland do.
Anagallis arvensis; pimpernel.
Geranium dissectum; meadow crane's bill.
Geranium columbinum; long-stalked do.
—— lucidum; shining do.
* Drosera rotundifolia; } sundew.
* —— longifolia; }
Saxifraga (various species); saxifrage.
Digitalis purpurea; foxglove.
Lepidium; pepperwort.
Delphinium consolida; larkspur.
Gentiana (various species); gentian.

Hyoscyamus niger; henbane.
Sempervivum tectorum; houseleek.
Cerastium aquaticum.
Lychnis vespertina; white campion.
Sherardia arvensis; field madder.
* Gymnadenia conopsea; scented orchis.
* Habenaria chlorantha; butterfly do.
* Orchis mascula; purple do.
* —— maculata; spotted do.
* —— pyramidalis.
* Ophrys apifera; bee orchis.
* Epipactis latifolia; helleborine, (Fig. 20).
* Parnassia palustris; grass of Parnassus.
* Pyrola (various species); wintergreen.
Monotropa hypopitys; bird's nest.
Elatine.
Sedum (various species); stonecrop.
Scrophularia (do.); figwort.
Antirrhinum (do.); snapdragon.
Linaria (do.); toadflax.
Trientalis Europæa.

FOREIGN AND GARDEN PLANTS.

Anethum aromaticum.
—— graveolens.
Argemone grandiflora.
Bidens nivea.
Catasetum.
Collomia grandiflora.
Coreopsis tinctoria.
Epidendrum (various species).
Capparis (various species); caper.
Gesnera.
* Hydrangea.
Eccremocarpus scaber,
Sphenogyne speciosa,
Lophospermum scandens, Fig. 22.
—— erubescens,
Bignonia,
} for membranous wing or border.
Dianthus barbatus; sweetwilliam.
Silene gallica.
Nigella; fennel flower.
Erica (various species); heath.
Mesembryanthemum (do.)
Limnocharis (do.)
Begonia (do.)
Petunia (do.)
Galinsogea parviflora.
Hyssopus officinalis.
Tagetes; African marigold.
Lychnis (various species).
—— chalcedonica; scarlet lychnis.
Reseda odorata; mignonette.
Nicotiana Langsdorffii.
Verbena nervosa.
Zygopetalum Mackayi.

Testa or seed-coat of Cobœa and Bignonia.

91. *Spores.* Acrogens or cryptogamous plants (such as ferns, mosses, lichens, fungi, seaweeds, &c.), do not produce true seeds, but extremely minute dust-like cellular bodies, called spores, from which new plants are produced. They differ essentially from seeds in having no germ or rootlet, but growth takes place from any part of their surface, and not from special fixed points as in seeds. Most spores are so extremely minute as to be quite invisible to the naked eye separately; but as microscopic objects they have several points of interest for us. One, which always delights those who see it for the first time, is the spore of the equisetum, Fig. 19. Of this plant there are several native species, from any of which the spores may be collected, and one or more is found in every locality. It is commonly known by the name of horsetail, and in the spring throws up a club-shaped head, brown or blackish in colour, which terminates the (generally) leafless stem. From this head, when mature, a greenish dust is readily discharged on its being touched or shaken. This

dust consists of the spores. If a little is thinly sprinkled on a very dry glass slide, it will be found, on viewing it through the microscope, to consist of a multitude of roundish bodies, each furnished with four long thongs or filaments, with enlarged ends. If the slide be now gently breathed on, these filaments will instantly coil round their respective seeds, and closely embrace them. As the moisture evaporates, the elastic thongs gradually uncoil, and in so doing, cause the spores to move about in the most singular manner, as if suddenly endowed with vitality. The most common English species are,—

Equisetum arvense; found in hedge banks and corners of fields. April.
— — limosum; in shallow and stagnant ditches and pools. June and July.
sylvaticum: shady woods. April and May.
— — Telmateia; watery and clayey places. April.

92. The spores of various hepaticæ are very interesting. The hepaticæ are a tribe of cryptogamic plants, most resembling mosses in general appearance; and by most ordinary observers unacquainted with botany, they would be so called. They differ from them, however, in two or three points, especially in their fructification. The leaves are cellular, ranged on either side of, or tiling the stem, or sometimes the plant consists only of a simple or forked leaf. The fructification is generally a globular head, most usually stalked, which, when ripe, bursts open into four segments. If one of these heads is selected when quite ripe, and laid on a glass slide, and after being adjusted to focus under a low power is touched with a needle, it will burst, and lay bare the spores with which it is filled. In most hepaticæ these are mixed with spiral filaments called *elaters*; these uncoil, and by their elasticity throw the spores to a great distance. This operation, as it proceeds under the microscope, is a most amusing and singular sight, appearing like a miniature bombardment from the frequent and forcible discharge of spores by the force of the elaters. These elaters themselves form interesting objects mounted in fluid. We shall have occasion to recur to the hepaticæ.

93. The spores of ferns are also well worthy of the attention of the microscopist. Some kinds are familiar to almost every one. They are the largest of cryptogamous plants, and exhibit some of the most elegant and graceful forms which the vegetable world displays. Usually they bear their fructification on the back of their leaves or fronds. Sometimes it appears in the form of a simple or branched spike, but on close examination it will be found that it is still at the back of the

leaves, which have rolled up as the fructification has advanced, so as to present the appearance of only a mass of spore-cases. But to understand the fructification of ferns, it will be best to take an example. A very abundant fern, growing in almost every locality, is the common polypody (*Polypodium vulgare*). It is found in hedgerows, at the foot of the stumps of trees, &c., and in a variety of similar situations. If a few fronds are gathered between May and November, the backs of some at least will be found to be spotted with raised roundish dots, especially towards the end of the frond. These spots are arranged in a double row on the back of each leafit or segment of the frond. When young, they are in many ferns (though not in *Polypodium*) covered with a white film ; this is termed the *indusium*, and the spot a *sorus*. If a frond not too advanced be selected, it will be seen that each spot appears rough, and of a bright yellow colour. If one of them be now scraped upon a glass slide and magnified, it will be found to consist of a large quantity of battledore-shaped bodies (Fig. 21), the curved margin being an elastic, jointed ring, nearly encircling a cellular membranous bag, which contains numerous spores. When ripe, the elastic ring straightens itself, and, in so doing, tears asunder the membranous capsule and scatters the spores. This structure may be beautifully seen in all its stages in fronds gathered during the time above-mentioned, especially about September. Some specimens may be mounted in balsam as transparent, and others as opaque objects. The development and growth of ferns may be observed by placing the spores in moistened flannel, and keeping it at a warm temperature. At first a single cellule is produced, then a second, and so on. After this the first cellule divides in two, and then the others, by which a lateral increase is obtained. The scales (ramenta) on the stalks, root-stocks, and backs of the fronds of ferns are well worthy of examination, and afford some beautiful objects. A list of some of these has already been given (sect. 48).

SPORES AND SPORE-CASES OF BRITISH FERNS.

Polypodium vulgare : polypody.
Lastræa Filix-Mas : male fern.
—— Thelypteris ; bog fern.
—— oreopteris ; fragrant heath fern.
Asplenium Adiantum nigrum ; black maiden-hair.
—— Trichomanes ; wall maiden-hair.
Scolopendrium vulgare ; hart's tongue.
Blechnum boreale.
Adiantum Capillus Veneris ; maiden-hair.
Pteris aquilina ; brake.
Ceterach officinarum ; scaly spleen-wort.
Osmunda regalis ; royal fern.

FOREIGN FERNS.

Acrostichum aureum.
Allantodia.
—— umbrosa.
Alsophila aspera.
—— lunulata.
Anemia fraxinifolia.
Aspidium auriculatum.
—— exaltatum.
Asplenium ambiguum.
Balantium calcita.
Cibotium Billardieri.
Cyathea Jamaicæ.
Davallia pyxidata.
Woodsia aspera.
Gleichenia. Gymnogramma.
Lomaria aurea.
—— Patersoni.
Sphæropteris.
Struthiopteris germanica.
Todea africana.
Lygodium hirsutum.
—— scandens.
—— volubile.
Meniscium palustre.
Nephrolepis.
Notholæna.
Polypodium plantagineum.
Pteris cretica.
—— elegans.
—— hastata.

94. *Mosses.* These minute but elegant plants are familiar to every one, and they afford a wide field of interesting research to the microscopist. Both the leaves and fructification are in very many species worthy of most attentive and minute investigation. Mosses are flowerless plants with leaves, and often possessing a stem, which is sometimes branched. From the stem or bosom of the leaves, a fruit stalk is sent up, bearing on its top an urn-shaped capsule, which is surrounded at its mouth with a fringe (sometimes double) of 4, 8, 16, 32, or 64 teeth (fig. 23). This is covered by a lid (*operculum*), and the whole is capped by a *calyptra* or veil. Within the urn-shaped capsule are contained the spores. When the capsule ripens the veil falls off first, and afterwards the operculum or lid; but as long as any damp weather is present the fringe remains closed over the mouth of the capsule. As it becomes dry, however, it expands, the teeth separate, and permit the spores freely to escape. The parts of mosses which will best repay microscopical examination are the leaves and fringe. In specimens which have been long dried, good objects may often be obtained from the leaves by relaxing them in water, when they will temporarily resume almost the appearance of fresh specimens. If the object is to be mounted dry or in balsam, suitable leaves should be selected and detached, and then redried between very dry blotting-paper, under a pressure of some 14 or 20 lbs. The fringe at the mouth of the capsule, however, must be obtained from fresh specimens; in those that have been dried for any length of time, it is often injured. If the spores have not been discharged, the capsule with its stalk should be detached from the plant and dried between folds of blotting-paper under pretty heavy pressure; if the capsule is empty, this is not

necessary; or, which is better still, the calyptra and lid being carefully removed, the fringe may be allowed to expand and dry, till the spores can be shaken thoroughly out; the capsule may then be mounted with its fringe.

95. It is not the common mosses, which render the "mossy banks" such attractive objects to the poet and lover of rural scenery, that will prove the most interesting objects for the microscope, but those more minute and less attractive ones to the ordinary eye which cover barren and chalky ground, damp banks, bare ground on heaths, walls and rocks, &c. &c. Very often beautiful microscopic specimens may be found in places where fresh soil has been upturned, or where turf has been pared off. The following list is confessedly very imperfect, and the scientific name only is given, as the common name "moss" will not serve to distinguish them in the hands of a person quite unacquainted with them; such, however, may generally obtain the assistance of some one in their neighbourhood who has a practical acquaintance with botany. Those marked (*) are common.

For Leaves.

Hookeria lucens.
—— læte-virens.
* Sphagnum cymbifolium (fig. 12).
* —— acutifolium.
Schistostega pennata.
Tetraphis pellucida.
*Dicranum bryoides.
—— adiantoides.
Bryum carneum.
* —— ligulatum.
—— punctatum.
* —— hornum.
* Polytrichum undulatum.
* Gymnostomum pyriforme.
* Hypnum complanatum.
* —— cordifolium.

The leaves of mosses are *best* mounted fresh, and in Deane's glycerine, No. 6. (Sect. 31.)

WHOLE PLANT.

Phascum subulatum.

For Fringes.

The capsule should be mounted with a portion of its stalk or seta, the lid (operculum) and veil (calyptra) being removed.

* Tortula unguiculata.
* —— ruralis.
* —— subulata.
Bryum intermedium.
Cinclidium arcticum.
* Polytrichum aloides.
* Funaria hygrometrica.
Grimmia apocarpa.
—— other species.
Splachnum ampullaceum.
Fontinalis antipyretica.

CALYPTRÆ.

* Encalypta vulgaris.
* Polytrichum juniperinum.

Section of young capsule of Funaria hygrometrica.

The capsule and fringe of Funaria hygrometrica is also a very pretty opaque object.

96. *Hepaticæ.* We have already spoken of this tribe of cryptogamic plants (sect. 92), and pointed out some particulars wherein they differ from mosses. Many of them afford interesting objects for a low power, when mounted

in fluid or in Deane's gelatine. We append a list of a fe of the most desirable.

* Jungermannia asplenioides.
* —— bidentata.
—— crenulata.
* —— Sphagni.
Jungermannia heterophylla.
—— barbata.
* —— scalaria.
—— polyanthos.
* Marchantia polymorpha, the conceptacles, as opaque objects.

97. *Algæ.* These are the plants so well known as seaweeds; and those green, hair-like weeds, so common in every stagnant pool, belong to the same tribe. The greenish scum frequently seen on ponds and wide ditches also often abounds with minute species. We cannot give any lengthened details here respecting them, but would just point out a few particulars worthy of notice, to serve as hints to the inquirer, and then append a list of some of the more interesting and easily accessible species. For descriptions we refer the student to *A Manual of British Algæ,* by W. H. Harvey, 9s.; published by Van Voorst, London; which is the best work at a small price which can be consulted in order to ascertain the name of any given specimen.

98. The *fresh-water algæ* are usually green and hair-like, and are found in almost every stagnant pool and ditch, and in many flowing streams, sometimes growing even on damp ground, mosses, or stones. Some species exhibit a very curious phenomenon, termed *conjugation.* Two parallel filaments at certain times of the year emit from their cells small tubes which unite with each other, and thus connect the two plants by a series of short cross tubes, giving them something of the appearance of a ladder with very short steps. This singular appearance is connected with the reproductive processes of the plant. In the same filaments the green colouring matter is usually seen to be disposed within their cells in dots, which are arranged in a spiral form, giving them a most elegant appearance under the microscope. In some species, the filaments are bent at right angles, and unite at these bends, without putting forth the tubes just described. The species in the following list marked (*) exhibit these curious peculiarities, and three or four of them are common everywhere.

99. Another genus, much more rare in its occurrence, but so beautiful that we may not omit a notice of it, is the *Batrachospermum.* Its filaments, when magnified, are seen to be surrounded at intervals by dense whirls of short branches, each of which resembles a necklace of beads. To the naked

eye the plant looks more like a dirty knotted thread, cased in a thin covering of jelly. The different species "inhabit mostly pure and moving waters, being usually found in fountains, wells, and streams, the force of which is not considerable. They are so exceedingly flexible that they obey the slightest motion of the fluid which surrounds them, and would almost seem to be endowed with vitality; nothing can exceed the ease and grace of their movements. When removed from the water they lose all form, and appear like little pieces of jelly, without trace of organization ; on immersion, however, the branches again quickly resume their former disposition." Dried specimens may be relaxed successfully by steeping for a time in water. All the species are beautiful; but in place of an enumeration of them, we will give a list of some of the chief localities where they have been found, as the more serviceable course. New River and River Lea, at Cheshunt; Cheshunt marshes; Lea Well, Devonshire; Tunbridge Wells; Penzance ; Plassey, near Limerick ; Cromaglan ; Loch Phadrick, Aberdeenshire ; brook in Clive-wood, Swansea ; Appin; Ferring near Arundel, &c. &c. ; more especially abundant in alpine and subalpine lakes, bogs, and streams.

100. Another very beautiful fresh-water alga is the *Hydrodictyon utriculatum,* which to the naked eye resembles a fine and delicate piece of green silk net. Magnified, the threads of the net are seen to be cells of a conferva, beautifully reticulated.

A very curious tribe is that comprising the genera *oscillatoria* and *nostoc,* many of the species of which exhibit such singular spontaneous movements that some have questioned whether they do not rather belong to the animal than the vegetable kingdom. They usually occur in dense patches or strata, either floating, or on damp ground or stones, composed of multitudes of straight, short, rigid filaments. The nostocs are usually in gelatinous masses enclosing the filaments. The colour of the oscillatoriæ is usually of a dark or bright green, rarely red. It is to the occasional appearance of countless myriads of a red species of nostoc that the Red Sea owes its name ; these minute algæ swarming in the water at periodical times for very many miles, and giving it a deep red colour. Some of the lakes of Ireland occasionally exhibit a bright green colour from the presence of vast quantities of other species.

FRESH-WATER ALGÆ. BRITISH.

* Zygnema quininum.
* —— deciminum.
* —— subventricosum.
* Tyndaridea bipunctata.
* —— stagnalis.
Hydrodictyon utriculatum.
* Mesocarpus scalaris.
* Mougeotia genuflexa.
Batrachospermum vagum.
—— moniliforme.
Stigonema atrovirens.
Conferva ægagropila.
Rivularia pisum.

101. The fresh-water algæ must always be mounted in fluids, as must most of the marine species. All the latter should, however, be soaked for a short time in fresh water to deprive them of salt. The fine hair-like species of sea-weeds will be found to be the most interesting, few of the frondose species having much attraction for the microscopist. The scarlet and purple kinds will be found best to reward investigation. Every part of the coast will afford some, though of course some spots are much richer in the number of the species than others. The coast of Devon is peculiarly rich both in sea-weeds and in its marine forms of animal life; and is a most delightful spot for the microscopist. The following list embraces a considerable number of the most beautiful microscopic objects among the British marine algæ; and in its compilation we have excluded all the rare species, as being so unfrequently obtainable that a list of them would be of little service. All the under-mentioned are frequent at least, and, as a slight guide, we have appended to each one of the numbers 1, 2, and 3. 1 signifying "frequent," 2 "common," and 3 "very common." For descriptions of the species, by which to identify them, we cannot do better than refer to Harvey's *British Algæ*, mentioned above.

RHODOSPERMEÆ.

1 Dudresnaia coccinea.
1 Ptilota plumosa.
2 —— sericea.
3 Ceramium rubrum.
1 —— Deslongchampii.
1 —— diaphanum.
1 —— gracillimum.
1 —— echinotum.
1 —— acanthonotum.
1 —— ciliatum.
2 Griffithsia equisetifolia.
1 —— corallina.
1 Wrangelia multifida.
1 Calithamnion plumula.
1 —— arbuscula
1 —— tetragonum.
1 —— polyspermum.
1 —— corymbosum.
1 Polysiphonia fibrata.
2 —— elongata, commonly called lobster's horns.
—— do. (transverse sections).
1 —— fibrillosa.
2 —— Brodiæi (tr. sect.)
3 —— nigrescens.
—— do. (tr. sect.)
1 —— atrorubescens.
1 —— byssoides.
1 Nitophyllum Gmelini.
2 Dasya coccinea.
—— —— tr sect. of lower part of stem.
—— —— fructification.
1 Jania rubens (macerated in acid before mounting); the ceramidia especially beautiful.
1 Delesseria alata.

Fig. 69.

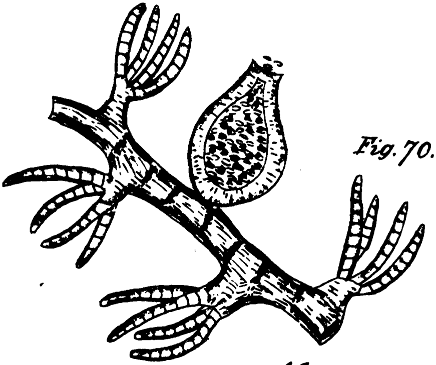


Fig. 70.

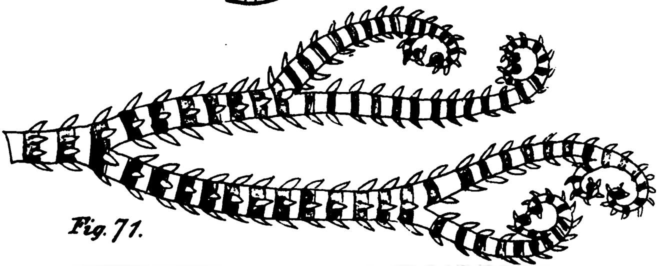


Fig. 71.

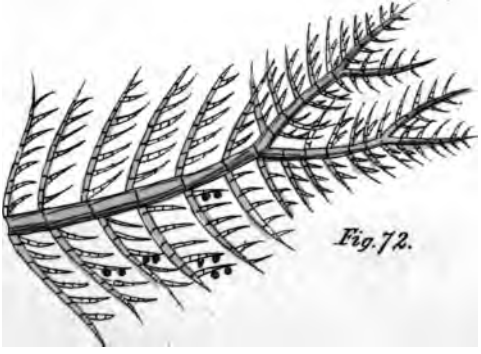


Fig. 72.

case, the linen should be pressed
the water expelled, the remainder
ttle, and the process repeated as
en carried home, the bottle will
foul water; but if it remain undis-
the Desmidieæ will sink to the
vater may then be poured off."
s the following interesting account
e minute organisms, which is very
esire to search for them:—"There is
near Keston, beyond Bromley, in
avensbourne takes its rise, where
of Desmidieæ and other fresh-water
From Bromley, walk on towards
ves Common and Bromley Common
or about another half-mile along the
the right hand; pass the reservoirs,
pace where there is a bog of about a
nt, and tending towards the right,
aths, ferns, and the beautiful *Drosera*
the lower part of the little stream
w trench in the Sphagnum, &c. By
stream you avoid the inconvenience
ise experienced, of the water being
equence of having to tread in the
centre of the little stream may be
pale pea-green colour flickering about
n your attempting to grasp it, most
ips through your fingers, from being
It consists of a hyaline substance,
all quantity of a bright green endo-
le branches, and this is the *Drapar-*
ier object is a mass of green filaments,
, and very slippery. When viewed
power, each filament is seen to be
bands of green dots, looking like a
and may be recognised as Zygnema,
Mesocarpus, and others. Keeping
sionally diverging a little on either
niature bogs and pools formed by the
raight down into the water, we shall
om a little mass of jelly, of a bright
merous brilliant bubbles of oxygen

CHLOROSPERMEÆ.

2 Cladophora fracta.
3 Enteromorpha intestinalis (high power).
1 —— erecta.
1 —— clathrata.
1 Ulva Linza.
3 Porphyra laciniata.
2 —— vulgaris.
2 Bangia fusco-purpurea.
Monormia intricata.

MELANOSPERMEÆ.

2 Halidrys siliquosa; tr. sect. of receptacle.
3 Fucus serratus; tr. sect. of receptacle.
1 Desmarestia viridis: tr. sect. of stems.
1 Arthrocladia villosa.
2 Litosiphon laminariæ.
2 Mesogloia virescens; minute portion of circumference of stem.
2 Myrionema; detached filaments of several species.
2 Sphacelaria scoparia; tr. sect. of stem.
3 Ectocarpus littoralis; fertile branch.

102. An interesting tribe is that termed *Desmidieæ* (fig. 24). They are a family of minute fresh-water algæ, sometimes consisting of a jointed filament, sometimes of a single frond. The joints, frustules, or fronds, are green, very varied in form, often elegantly figured or sculptured, sometimes ornamented with spines or forked projections, and almost always separable into two symmetrical valves or segments. They are not readily decomposed, but are, when recent, enveloped in a mucous or gelatinous covering. The frustules are never silicious, and they are by all, or nearly all observers, admitted to be true vegetables. They have been but little studied until recently, but Mr. Ralfs's beautiful work, *The British Desmidieæ*, has attracted great attention to them, and to that work we must refer the inquirer for descriptions and figures of the different species, and for full details as to their structure, &c. We have not room for these particulars here, and shall be best furthering the aim of this work by giving some concise directions for finding and obtaining them, for which we are indebted to Mr. Ralfs's book.

103. "As the Desmidieæ are unattached, and very minute, they are rarely gathered in streams. In small shallow pools, that do not dry up in summer, they are most abundant; hence pools in boggy places are generally productive. The Desmidieæ prefer an open country. They abound on moors and in exposed places, but are rarely found in shady woods or in deep ditches. To search for them in turbid water is useless. Such situations are the haunts of animals, not the habitats of the Desmidieæ, and the waters in which the latter are present are always clear to the very bottom. In the water, the filamentous species resemble the Zygnemata, but their green colour is generally paler and more opaque. They

often occur in considerable quantity, and, notwithstanding their fragility, can generally be removed by the hand in the usual manner. When they are much diffused in the water, I take a piece of linen about the size of a pocket-handkerchief, lay it on the ground in the form of a bag, and then by the aid of a tin box, scoop up the water, and strain it through the bag, repeating the process as often as may be required. The larger species of Euastrum, Micrasterias, Closterium, &c., are generally situated at the bottom of the pool, either spread out as a thin gelatinous stratum, or else collected into finger-like tufts. If the finger be gently passed beneath them, they will rise to the surface in little masses, and with care may be removed and strained through the linen, leaving only a mere stain or a little dirt; but by repeated fillings up and strainings a considerable quantity will be obtained. If not very gelatinous, the water passes freely through the linen, from which the specimens can be scraped up with a knife, and transferred to a smaller piece; but in many species the fluid does not at length admit of being strained off without the employment of such force as would cause the fronds also to pass through; and in this case, it should be poured into bottles until they are quite full. But many species of Staurastrum, Pediastrum, &c., usually form a greenish or dirty cloud upon the stems and leaves of the filiform aquatic plants, and to collect them requires more care than is necessary in the former instances. In this state the slightest touch will break up the whole mass, and disperse it through the water. I would recommend the following method as the best adapted for securing them:—Let the hand be passed very gently into the water, beneath the cloud, the palm upwards, and the fingers apart, so that the leaves of the invested plant may lie between them, and as near the palm as possible; then close the fingers, and keeping the hand in the same position, but concave, draw it cautiously towards the surface, when, if the plant has been allowed to slip easily and with an equable movement through the fingers, the Desmidieæ, in this way brushed off, will be found lying in the palm. The greatest difficulty is in withdrawing the hand from the surface of the water, and, probably, but little will be obtained at first; practice, however, will soon render the operation easy and successful. The contents of the hand should be transferred at once to a bottle, or in case much water has been taken up, into the box, which must be close at hand; and when this is full, it can be emptied on the linen as before. But in this case, the linen should be pressed gently, and a portion of the water expelled, the remainder being poured into the bottle, and the process repeated as often as necessary. When carried home, the bottle will apparently contain only foul water; but if it remain undisturbed for a few hours, the Desmidieæ will sink to the bottom, and most of the water may then be poured off."

104. Mr. Shadbolt gives the following interesting account of a good locality for these minute organisms, which is very suggestive to those who desire to search for them:—"There is a piece of boggy ground near Keston, beyond Bromley, in Kent, where the river Ravensbourne takes its rise, where many interesting species of Desmidieæ and other fresh-water algæ may be procured. From Bromley, walk on towards Keston, passing over Hayes Common and Bromley Common on the right; continue for about another half-mile along the road, and then turn to the right hand; pass the reservoirs, and approach an open space where there is a bog of about a quarter of a mile in extent, and tending towards the right, make your way among heaths, ferns, and the beautiful *Drosera rotundifolia* (sundew), to the lower part of the little stream rippling through a narrow trench in the Sphagnum, &c. By working your way up the stream you avoid the inconvenience which would be otherwise experienced, of the water being rendered turbid in consequence of having to tread in the boggy ground. In the centre of the little stream may be observed something of a pale pea-green colour flickering about in the current, which, on your attempting to grasp it, most likely eludes you, and slips through your fingers, from being of a gelatinous nature. It consists of a hyaline substance, with a comparatively small quantity of a bright green endochrome, disposed in little branches, and this is the *Draparnaldia glomerata*. Another object is a mass of green filaments, rather harsh to the touch, and very slippery. When viewed with a lens of moderate power, each filament is seen to be surrounded with several bands of green dots, looking like a ribbon twisted spirally, and may be recognised as Zygnema, Tyndaridea, Mougeotia, Mesocarpus, and others. Keeping up the stream, and occasionally diverging a little on either side of it, among the miniature bogs and pools formed by the Sphagnum, on looking straight down into the water, we shall probably see at the bottom a little mass of jelly, of a bright green, studded with numerous brilliant bubbles of oxygen

gas. This is the general appearance of most of the Desmidieæ, as Micrasterias, Euastrum, Closterium, Cosmarium, &c. The spoon is also a handy tool in this case, though, by practice, the finger will do nearly as well; the chief difficulty arises when the specimen is brought to the surface of the water, it not being easy to get it out without losing a considerable portion of it. Little pools in the bogs made by the footsteps of cattle are particularly good spots to find Desmidieæ, many species being in a very contracted space. The most prolific bog is at Tunbridge Wells, near a house known as Fisher's Castle, not far from Hurst Wood. There is also a good one at Esher, at a spot called West End."

Another minute tribe of algæ, the *Diatomaceæ*, are als very interesting to microscopists. The larger proportion o the species have, however, until very lately, been considered as animalcules; and as a considerable number of naturalist still so consider them, we have preferred to speak of them under that head.

105. *Fungi.* The fungi are a very extensive tribe of plants which have been aptly called "the scavengers of nature," an some of the larger species are familiar to every one, a mushrooms, toadstools, and puff-balls. They are extremel numerous, about 4000 species having been already described and vast numbers of kinds without doubt yet remain un known, to reward the investigation of those who may devot their attention to them. They most commonly grow upo decaying substances, which, if left to decompose and putrif unaided, without furnishing nutriment to other forms of life would probably prove not only annoying but noxious. Bu wherever vegetable matter is in a state of decay, there th spores of fungi, which are always floating in the air, fix a their appropriate soil, and spring up readily, thus convertin the decomposing organic material into new and vigorous livin structures. They are astonishingly fertile, and of exceedingl rapid growth. A large fungus of the puff-ball kind has bee seen to grow in one night, from a mere speck to the size of large gourd; and the fact must be familiar to every one wit what great rapidity many vegetable substances becom covered with mould, which is one of the minuter fungi. Th larger plants of this class do not present any structure whic would be regarded with special interest by the microscopica observer, but among the very minute ones a great variety o very interesting objects may be found. We can only describ

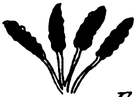


Fig. 25.

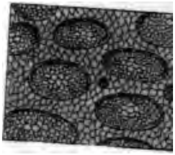


Fig. 26.

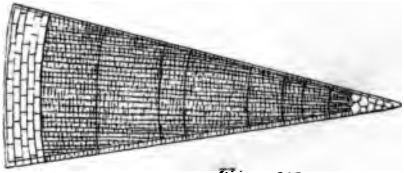


Fig. 27.

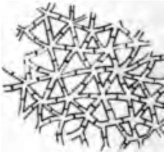
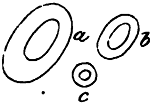


Fig. 28.



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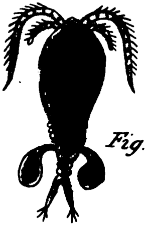


Fig. 30.

Fig. 31.

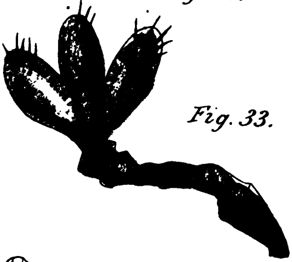
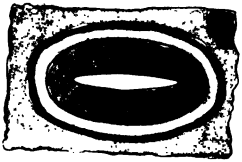


Fig. 33.



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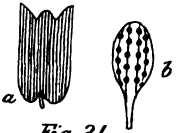

Fig. 34.

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three or four as examples, but can assure any one who will take up this class of objects, that many and very curious structures are to be found with a little attention and patience.

106. If any one will examine the backs of some of the leaves which remain on the common bramble after most trees have become bare, say in November, he will most likely find a few black spots on it, like minute specks of soot. If one of these is scraped carefully into a little Canada balsam, heated and mounted, it will be found to consist of a large assemblage of elongated club-shaped bodies (fig. 25), composed of several cells of a dark brown colour, and elevated on a slender transparent pedicel. This will probably be the *Phragmidium incrassatum*, and is one of the numerous family of microscopic fungi. The disease which attacks the ears of wheat, called by farmers smut, brand, bunt, &c., is a very common one, and specimens may be obtained in every locality. It consists of a minute fungus which grows within the grain of wheat, as it ought to approach to ripeness, till it entirely destroys its contents, filling the grain with its own spores. If a kernel of wheat thus affected be broken by the fingers, they will be covered with a black dust, which is the fungus in question, and is characterized by an offensive smell, resembling that of stinking fish. It is named *Uredo fœtida* by botanists, and an achromatic lens of high power will exhibit its rough globular spores, connected by threads of mycelium or spawn. A still commoner species of smut (*Uredo segetum*) is recognised by the black, shrivelled, dusty appearance of the ears of wheat or barley, but its spores are very minute, and not of much interest as an object. A better one is the *Uredo rubigo*, known to farmers as the red-rust. Stems of corn which are *mildewed* (as it is termed), will afford to the observer specimens of another fungus (*Puccinia graminis*) considerably resembling that affecting the bramble leaf. These fungi are also club-shaped, and elevated on a slender stalk, but the spore head is divided into only two cells. The sporules enter the growing plant by its pores or stomata, and immediately propagate themselves, the mycelium or spawn spreading through the cells of the stem till the spores are formed, when they burst through the epidermis, and exhibit their mature form. Very many scientific men attribute the potato disease to a similar growth of a fungus through its cells. One thing is certain, that a minute fungus is *almost* invariably, if not always present on the diseased plants. It is called *Botrytis infestans*, and

bears its round spores in a bunch at the top of the stem, something like a bunch of grapes, whence it derives its name. The grape disease is owing to, or at least is always accompanied by, a microscopic fungus (*Oidium*), and a very fatal disease among silkworms is due to a similar cause. Some diseases of the human body are connected with the development of fungi, and it is believed by some that that fearful malady, cancer, will be proved to be "a vegetable growth, or conversion of the nutritive cell into that of a fungoid vegetable."

107. But these must serve as examples. Multitudes more are readily accessible. Mildew, as it is termed, is usually owing to one species or other; and on leaves and stems of wood, especially when they are in a state of incipient decay, many other species may be readily obtained. The common appearance of such is a brown or black stain or spot, often looking like a minute flake of soot, &c. As a specimen, we give a list of some interesting species, with the plants on which they are found.

Name.	*Grows on*
Puccinia graminis,	Corn stalks and grasses.
—— Caricis,	Carex acuta.
—— arundinacea,	Reeds (arundo).
—— Asparagi,	Garden asparagus.
—— scorodoniæ,	Woodsage (Teucrium scorodonia).
—— Circeæ,	Enchanter's nightshade.
—— Geranii,	Herb Robert (Geranium Robertianum).
—— Lychnidearum,	Pinks, carnations, campions, &c.
—— Calthæ,	Caltha palustris.
—— virgaurea,	Solidago virgaurea.
—— Ægopodii,	Ægopodium podagraria.
—— Epilobii,	Epilobium montanum.
—— Saxifragarum,	Saxifraga granulata.
—— Polygonorum,	Polygonum amphibium.
—— Bardanæ,	Burdock.
—— Prunorum,	Plum and sloe.
These last two species are beautifully sculptured.	
Botrytis infestans,	Potato.
—— parasitica,	Turnips, cabbage, &c.
—— vulgaris,	Common on rotting plants.
—— destructor,	On onions.
Phragmidium incrassatum,	Roses and brambles.
—— potentillæ,	Various species of potentilla.
Penicillium brevipes,	Stem of elder.
Aspergillus glaucus,	Decaying vegetables; the blue mould of cheese.
Sporidesmium fasciculare,	Birch wood.
—— pyriforme,	Rotten pine wood.
Rhodocephalus candidus,	Beech bark.
Brachycladium penicillatum,	Mallows, poppies, celandine, &c.
Erysiphe castagnei,	Hop mildew.

Name.	*Grows on*
Æcidium (yellowish, reddish, or brownish spots in leaves).	
—— Euphorbiæ,	Spurges.
—— Berberidis,	Barberry.
—— Urticæ,	Nettles.
—— compositarum,	Composite plants.
—— Menthæ,	Mint.
—— Grossulariæ,	Gooseberry.
—— cancellatum,	Pear.
—— cornutum,	Mountain ash.
Oidium Tuckeri,	Grape mildew.
Prosthemium betulinum,	Bark of branches of birch.
Torula (various species),	Dead stems of plants.

108. It now only remains to make a few remarks on the circulation in plants. Few of the phenomena which the microscope unveils to us in the vegetable world exceed this in interest. Of its cause, and utility, we can give little or no account. Various theories have been started to account for it, but on these we need not descant, as nothing certain is known. We can here, therefore, only give directions how to see it, and in what plants to look for it. The following aquatic plants exhibit it, and have the advantage of showing it with a moderately low power.

Chara (Nitella) translucens. Several species of Chara exhibit this phenomenon. They are all water plants, thread-shaped, with similar branches arranged in whorls at intervals along the main stem. This and the three following species are translucent and glossy. They bear on the branches small nuclei or seeds, which are *spirally twisted.* These will readily distinguish them from other water plants of similar appearance. Besides these they bear small globules, each of which at length bursts into eight valves: these valves are very curious objects examined in fluid. A small branch of this species under the microscope beautifully exhibits this curious spectacle, which consists in a circulation of the fluid around and within the cell in which it is contained. It is rather rare. Habitats: deep stagnant pools near Shrewsbury; Browston, Suffolk; Baguley Moor, Cheshire; several places in Scotland.

Chara flexilis. Ditches, lakes, and rivers, frequent.

Chara nidifica. Salt-water ditches at Shoreham, Sussex; and Cley, Norfolk.

Chara gracilis. Fish ponds in Jersey. Boggy pools in St. Leonard's Forest, Sussex. Llyn Idwell, North Wales.

Chara vulgaris. Ditches and slow streams, frequent. This is the commonest of the whole genus, but unfortunately it is by no means so easy to see the circulation in it as in any of the foregoing. It may best be observed in the transparent tips of very young branches. The main branches are usually surrounded with a close coat of minute tubes which pass in a spiral direction around the stem: if these be scraped off, the circulation can be observed in the stem and branches, but this is an operation of some difficulty, and involving considerable delicacy of hand. Sometimes portions of the branch can be found free from the investing tubes: these may be successfully used.

109. *Vallisneria spiralis.* This is a foreign plant occurring abundantly in streams in Germany. It is often cultivated in England on account of its curious manner of flowering, and for seeing the circulation in its cells. It grows entirely beneath the water, has long grass-like leaves, and sends up its female flowers on long spiral stalks, so that they may always float on the water, however variable its depth. The male flowers become entirely detached from the plant when ready to open, rise to the surface, expand, and, ere they float away, shed their pollen over the female flowers. It is in the leaves of this plant that we shall find this beautiful phenomenon of the circulation exhibited. The best way of seeing it is to take a small portion of a young leaf and divide it in halves by making a very oblique section on the plane of the leaf, by which means a transparent end is obtained. This should be done at least an hour before it is put under the microscope. The part is to be viewed in water between two pieces of glass, and a little heat is sometimes useful in causing the movements to commence.

110. *Hydrocharis morsus-ranæ*, or frogbit, is an aquatic plant very frequent in stagnant ditches and pools, and may be readily recognised by its roundish kidney-shaped floating leaves about the size of a shilling. The stipules, or little leaf-like appendages at the base of the leaf-stalk, and the ends of the roots, are the parts used. Some species of *Potamogeton* or pondweed, and the cellular tissue of the young leaf and shoots of *Sagittaria sagittifolia* (arrow-head), also may be used for the same purpose.

But, perhaps, the best plant of all is *Anacharis alsinastrum*, a plant very abundant in some parts of our country, in rivers and reservoirs. It is the "new water-weed" of which so much has been said in the newspapers, and which has threatened serious consequences from its extremely rapid growth, impeding the flow of rivers. It may very easily be cultivated, and perhaps the best way for a microscopist is to have a small quantity of this or the *Vallisneria*, or both in a growing state. The easiest method is to put a small quantity of washed sand and gravel into the bottom of a glass jar, of any convenient size, from half a gallon upwards; plant the plants in the sand, and then fill up with water very carefully so as to disturb the bottom as little as possible. When it has settled, put in two or three freshwater snails (*Lymnæa stagnalis* and *Planorbis corneus* are the best), and the plants will grow and keep healthy for years. All that requires to be done is to add water as it may evaporate, and when the plants become too thick, to thin them out. The circulation may be seen in the cells at the edge of the leaf.

111. Hairs of the following plants exhibit the same phenomenon, but require an achromatic lens of high power to witness the currents:—

Tradescantia virginica. Hairs from the calyx and stamens.
Senecio vulgaris—(Groundsel). Hairs of the stalk and flower.
Urtica baccifera. The stinging hairs.

In a few plants the motion of the elaborated sap (or *latex*, as it is termed), may be observed. Those best adapted for the purpose are species of *Ficus*, *Euphorbia*, and *Chelidonium*. Small portions of the leaf, and unexpanded sepal of *Chelidonium majus* (the greater Celandine), will show the currents of orange-coloured granules in their appropriate vessels.

CHAPTER VI.

OBJECTS.—THE ANIMAL KINGDOM.—VERTEBRATA.

112. In proceeding to describe the objects afforded by the animal kingdom for the microscope, we shall take them up somewhat in systematic order, as affording the more easy mode of classifying them, and as enabling us also to point out their connexion with some leading facts of natural history and comparative anatomy. The first great section of the animal kingdom, the vertebrated animals, comprising mammalia, birds, reptiles, and fishes, is not generally considered one of the richest fields for the microscopist. The size of the animals comprised in it renders any magnified representation of their bodies or limbs quite needless; nevertheless, there are many

parts of their internal structure which present points of great interest, and which often require the higher powers of the microscope to develop with clearness.

113. *Bone.* True bone is peculiar to the vertebrate animals, and the possession of it is one of their most distinguishing characters. It forms the framework which gives solidity to their whole structure, and consists of membranous or gelatinous animal matter, within and amongst which earthy material is deposited, which renders it hard, strong, and durable. Bone, in living animals, is living too; it is permeated with innumerable channels and blood-vessels, which convey nutriment to the bone, and absorb and carry off superfluous and dead matter. Its structure may be readily observed by making a thin transverse section. This will exhibit, when magnified, numerous dots of considerable size scattered over the surface. These are the cut ends of canals or vessels which traverse the bone in a longitudinal direction, and are called the Haversian canals. Their office is to give passage to the blood-vessels. Ranged round these will be seen concentric circles of smaller dots, and wavy irregular lines radiating from each, so as to connect them with each other. These smaller dots are called *bone-cells* or corpuscles, and the fine lines connected with them are small tubes or tubules. These bone-cells aid in performing the function of circulation and nutrition in the bones, and it is said that a fluid poured into one of these cells might, by means of the tubules, find its way into every other cell in the bone. So various are the forms, sizes, and characters of these bone-cells and their tubules, that it is very probable, that by a careful comparison of specimens, not only might the class, but even the genus, and perhaps the species of animal to which a mere fragment of bone belonged be ascertained. Sections are best obtained from a long bone, such as the tibia (leg-bone) or femur (thigh-bone), or the bones of the fore-leg or arm. The best mode of proceeding is to cut, by a fine saw, a thin transverse slice, and then proceed to thin and polish it in the manner already described for hard vegetable tissues (Sect. 59.) A precaution, however, is necessary. The balsam used must be old and hard, and no more heat should be employed than is necessary to make the balsam adhere to the section and glass: if it is allowed to penetrate the texture of the bone, it will render the bone-cells and tubules almost, if not quite, invisible. Fossil bones must be cut in the mode directed for fossil woods. The following will afford some of the most interesting varieties:—

MAMMALIA.
Human bone (tibia).
,, treated with muriatic acid.
,, clavicle.
Ox.
Lion.
Horse.
Mouse.
Elephant.
Camel.
Bat.
Rhinoceros.
Stag.
Whale.

BIRDS.
Penguin.
Swallow.
Ostrich (femur).
Albatross.
Common fowl.
Dinornis.

REPTILES.
Turtle (shell or carapace).
,, (humerus).
Tortoise.
Toad.
Snake.
Newt.
Frog.
Pterodactyle (humerus).
Crocodile.
Boa (vertebra).
,, (rib).
Alligator.
Siren (cranium).

FISHES.
Turbot.
Cod.
Conger eel (lower jaw-bone).
Eel.
Flying fish.
Lepidosteus.
—— (scale).
Ray, spine.
Shark (vertebra).
Silurus (spine).
Sturgeon.
Sword fish (sword).
Trygon (scale).

114. *Horn* is nearly allied to bone in its structure, and that of the rhinoceros is one of the most beautiful illustrations of bony structure that can be exhibited. Sections of horn may often be cut as directed for wood; and all the very tough kinds are easily cut after being boiled for a short time in water: they must be then cut while warm.

Cartilage or gristle contains no blood-vessels in its natural state, but consists of a fine, semi-transparent, gelatinous substance, cavities, and cells. It is highly elastic and flexible. It is nourished by absorption, apparently from cell to cell, in the same mode in which cellular vegetables grow. In very young vertebrate animals the bones themselves are cartilaginous, and the gradual conversion of cartilage into bone may be distinctly traced. The articulating ends of some bones, such as the ribs, femur, &c., are cartilaginous, and a section of such a bone at the points of union will exhibit the gradual passage of the one into the other in an interesting manner. The following will exhibit interesting examples:—

Cartilage, human, from concha of ear.
,, ,, Intervertebral.
,, ,, Ribs (with bone).
,, ,, Trachæa.
,, ,, Epiphysis of lower end of humerus.
Cartilage, ear of mouse.
,, ,, rabbit.
,, Cuttle-fish.
,, Head of skate.
,, Frog.

115. *Teeth.* These are in some respects very similar to bone; but, nevertheless, require a separate notice. A tooth usually consists of three distinct structures, the relative proportions and arrangement of which constitute the chief differences in the teeth of various animals. These are, 1. Ivory, which forms, usually, the bulk or body of the teeth; 2. Enamel, which is much harder, and usually forms the crown; and 3. Cortical or bony substance, which is found covering the

fang. These three differ not only in their minute structure, but also in hardness, and in the proportions of earthy matter they contain. The enamel is generally so hard as to strike fire with steel, and consists of about two parts of animal matter to ninety-eight of earthy (phosphate and carbonate of lime). The ivory is less dense, and contains twenty to twenty-nine parts of animal with seventy-one to eighty of earthy material; while in the bony portion, the proportion of animal matter is nearly double that of the ivory. The *enamel* is found, on microscopical examination, to consist of crystalline six-sided columns or prisms, each about $\frac{1}{5000}$th of an inch in diameter. The end of these prisms rests on the ivory, the other forms the surface of the tooth. The enamel in human teeth, and those of the carnivora, forms the whole crown of the tooth; but in some herbivorous animals (elephant, &c.) it is arranged in upright plates, with the ivory and bone between them; and in the squirrel and other rodentia the front surface of the gnawing teeth only is covered with enamel. The *ivory* contains a vast number of minute wavy tubes which commence in the central cavity and pass towards the surface of the tooth. These tubes contain or deposit the earthy matter. The bone of teeth is formed like ordinary bone, but the cells, &c., are more irregular. Teeth may be cut in the same manner as bone, but the best kind of saw is that used for iron and brass, and hones of the water of Ayr stone, and a strap of buff leather charged with putty powder may be used for the purpose of polishing. The following are the most interesting:—

Rat.
Ox.
Mouse.
Horse.
Bear (molar).
Hippopotamus.
Pig.
Fox.
Dog.
Deer.
Cat.
Elephant.
Walrus.
Sheep.
Tiger.
Sperm whale.
Ass.
Saw-fish (Pristis).
Myliobates (Eagle Ray, opaque object).
Shark.
Pike.
Salmon.
Halibut.
Eel.
Conger eel.
Codfish.
Catfish.
Ptychodus.
Chimæra.

116. Fossil teeth may be cut as directed for fossil wood and bone (Sect. 83.) The value of sections of teeth is very great, especially to the geologist and comparative anatomist; for Professor Owen has shown in his great work on *Odontography*, how the teeth of animals exhibit marked and characteristic differences in different species, not only in their external form, but in their internal structure and arrangement. We cannot pursue the subject here, but must refer

to his work, which is replete with information and most interesting illustrations.

Here, perhaps, we ought to mention *whalebone*. This is neither bone nor tooth, but is more analogous to the gum. In some species of whale, especially in the Greenland whale, which has no true teeth, it hangs from the palate in broad plates, the free end being a long fringe of fibres. Its use is to strain out from the water the small medusæ, mollusca, and crustacea, which are the food of the whale. A thin slice may be cut across the fibres, and forms a very beautiful object.

117. *Blood*, when first exuded from the body, is liquid, and appears perfectly uniform; but under the microscope it is seen to be threefold in composition, a nearly colourless fluid, holding in suspension numerous red disks (Fig. 29) and fewer pale ones. When allowed to stand for a time, fibrine separates from the liquid part, and inclosing with it the red disks, forms a clot. In nearly all the mammalia the blood-disks are circular, but hollowed in the centre. They are not membranes containing a liquid, but are uniform in structure throughout. They may be made by pressure or extension to alter their shape. This character of flexibility and elasticity is well seen in viewing the circulation of the blood through the minute and capillary vessels, when a blood-disk will often be seen to pass a space much smaller than itself, recovering its ordinary form immediately afterwards. In birds, reptiles, and fishes, they are somewhat oval, with a swelling in the centre. They vary very much in size. The smallest are found in the musk-deer, not exceeding $\frac{1}{12000}$th of an inch in diameter. In human blood they average $\frac{1}{3500}$th of an inch; in the elephant about $\frac{1}{2700}$th; in birds they vary from $\frac{1}{1700}$th to $\frac{1}{2400}$th. In the frog they are about $\frac{1}{1000}$th of an inch; in fishes commonly somewhat larger; in the siren $\frac{1}{435}$th, and in the proteus $\frac{1}{337}$th. These are the largest known. The office of the red disks appears to be the conveyance of oxygen from the lungs to the various tissues and organs, and to carry off the superfluous carbon which is exhaled as carbonic acid from the lungs. The colourless disks or globules are probably the new nutriment taken up by the blood, and held in it for the formation of new parts, or to replace the waste of old ones. To mount blood-disks, spread a very small quantity in the thinnest possible layer upon a glass slide, which must then be passed rapidly backwards and forwards through the air, so as to dry the blood as quickly as possible, when the disks will be found

to have altered but little in shape; then cover with very thin glass, and cement the edges with gold size thickened with litharge, with two or three coats of black japan to finish. The following are worth mounting:—

Human (Fig. 29, *c*).
Sheep.
——
Swallow.
Goose.
Ostrich.

Common fowl.
——
Frog (Fig. 29 *b*).
Newt.
Green lizard.
Toad.
Siren.

Proteus (Fig. 29 *a*).
——
Eel.
Perch.
Salmon.
Skate.

118. *Circulation of the blood.* This is one of the most magnificent sights which the microscope can reveal. When first discovered about 200 years ago by Harvey, it was ridiculed on every hand, and obloquy and invective were unsparingly heaped upon him. With him, though logically deduced, it still was a theory, but we can obtain, what is always more valuable than the best-supported theory, ocular demonstration of the fact. We have already, in describing the frog-plate (Sect. 12), given some directions for viewing it. To the directions given there, we may offer some additional. Mr. Hassall gives directions for viewing it in the tongue of the frog, which is soft, pulp-like, and easily extensible, without any risk of rupture, into a thin transparent membrane. To view it, however, it must be kept extended by fastening it in this expanded state, by four or five pins thrust through it into the cork-disk to which the frog is fastened. Whether or not this occasions pain to the animal, it has the appearance of cruelty—a consideration which will deter any right-minded observer from risking the infliction of unnecessary suffering on a harmless animal, even though a sight of great magnificence be obtained thereby; the more especially as the same spectacle can be seen *without* inflicting pain.

119. A good substitute for the frog-plate described in sect. 12 is a piece of cork, such as is prepared by cork-cutters for soles, about 9 inches long and 3 wide, with a hole in the middle about $\frac{1}{2}$ or $\frac{3}{8}$ inch in diameter. The frog may be secured in wet calico instead of a bag; but care must be taken that the bandages and tapes do not press too tightly either upon the body or limbs, or the circulation may be obstructed. The toes may be tied by thread to pins stuck into the cork, and the web should be kept constantly moist with water. Dr. Carpenter also states, that it may be well exhibited in the tail of very young tadpoles; and as the constant state of motion in which they are naturally would

greatly interfere with such observations, he recommends that hot water should be gradually mixed with that in which the animal is swimming, till the temperature rises to 100 or 110 deg. It then becomes motionless, but is uninjured, and the circulation is maintained; and as the water becomes cold it resumes its usual agility.

120. The larva of the water-newt, we are informed by the same authority, exhibits it most beautifully in its external gills and in its feet. Inclosed in a large aquatic box, gentle pressure is to be made on its body so as to stop its movements without impeding its circulation. One of the most beautiful displays of this phenomenon is on the yolk bag of young fish soon after they have been hatched. The yolk bag then continues for some time dependant from the under part of the abdomen, its contents not having been absorbed while in the egg, as is the case in birds. For some time after hatching, too, the fry continue motionless, so as to give every facility for observation. There are still other sources to which the observer may have recourse for living animals in which to see this magnificent spectacle. The ear of the young mouse, and the fins and tail of the gold-fish, stickleback, carp, and most small fish, all may be used for this exhibition.

There is a kind of diffused circulation in some of the lower animals which we will defer any account of till we come to speak of them.

121. The circulation of the blood is always a sight replete with interest; and when we consider its vital importance, the essential processes of repairing waste, supplying nutriment, and removing effete matter, which it has to effect, the amount of force which is required to maintain it, and the unceasing regularity with which it is continued every moment of life, the interest with which it is viewed will be greatly enhanced. At every stroke the heart contracts with a force of many hundred, some say many thousand pounds, and it beats 4000 times in an hour, while the whole mass of blood is stated to pass through the heart (and therefore through the capillaries) completely every six minutes. One of the most interesting results of modern microscopic observation on the circulation of the blood is the light it has thrown on the cause of inflammation. If the membrane of the frog's foot, while under the microscope, be touched with the smallest drop of any stimulant (spirits of wine, for example), the even flow of the current of blood will be seen to be arrested, in consequence of the white or colourless blood-disks adhering to the sides of

the vessels, leaving the course still free for the passage of the red disks. If the stimulant cease to act, they are gradually taken up, and the circulation will proceed as before; but if the irritation be kept up, the vessels become at length quite obstructed, and inflammation is the result.

122. *Injections.* The arteries and veins of the bodies of animals, though large near the heart, and sufficiently visible in their branches to a considerable distance from it, ultimately ramify to such an extent that their fine branches are invisible to the unaided eye, and from this minuteness and their hair-like form, they have received the name of *capillaries.* It is by means of the capillaries that the blood, having reached the extremest parts of its circuit, passes from the arteries into the veins, and is re-collected into those main trunks which carry it back to the heart. It is by their means that all the functions which the blood has to perform are carried on. Hence, in those parts of the body where the active vital processes are being carried on, we find the capillaries clustering thickly, exposing a large surface of membrane, within which blood is flowing constantly. Thus, on the walls of the air-cells of the lungs, on the coats of the stomach and intestines, the thickly-spread capillaries are objects of great attractiveness to the microscopist and anatomist.

123. In inspecting such portions of the body of any animal, the arteries being all emptied of blood after death, it is often difficult to distinguish the capillaries from other parts of the structure; and, therefore, the practice has generally obtained of throwing into some of the larger vessels a coloured fluid with such an amount of force as to compel it to fill up all, even their minutest branches; and those injections have been preferred which, though liquid when used, afterwards set into a solid. We shall very briefly describe the method of proceeding, and refer the reader to some one of the works named in sect. 212 (1.) for further directions. A very full account will be found in Dr. Beale's *How to work with the Microscope.* The solution for injecting may be prepared as follows. Of this there are two kinds, one of which is intended for opaque objects, the other for transparent ones. The former is most frequently used, but is most difficult of management; the latter is easier, but does not make such splendid-looking objects.

124. FORMULÆ. No. 1. *For opaque injections.* 1 oz. gelatine, soak in 4 oz. cold water till soft, add 4 oz. more water and boil till dissolved, then add either 1 oz. vermilion

or 1¼ oz. orange chrome yellow. Whichever is used, *it is indispensable* that they be very finely levigated. The coloured size must frequently be stirred; always, indeed, before filling the syringe.

No. 2. *For transparent injection.* Spirit of wine, 1 oz.; wood naphtha, 1½ drachm; mix and add glycerine, 1 oz.; then add, by degrees, water, 2 oz.,—call this solution A. Now prepare separately the two following solutions: 1. Ferrocyanide of potassium, 12 grains; water, 1 oz.—dissolve. 2. Tincture sesquichloride iron, 1 drachm; water, 1 oz.—mix. Next very gradually add the iron solution to the ferrocyanide, well shaking them at every addition. Finally, with this deep blue solution, mix the above colourless solution A gradually, and with frequent shaking.

125. The apparatus required will be as follows:—An injecting syringe with stop-cock, several pipes for insertion into the artery or vein, and a copper can for holding the fluid to be used, to be set in hot water so as to keep the injection in a fluid state. If the opaque injection is used, the part intended to be operated upon must be kept in hot water for a considerable time previously (in the case of large portions, for some hours), else, from not being heated throughout its substance, the injection may set and obstruct the vessels before reaching the capillaries. For the same reason, the specimen must be kept in hot water during the process of injection, and the operation must be quickly performed. Too much force, however, must not be used in forcing the injection into the vessels, or some of them may be ruptured. All things being in readiness, proceed as follows:—Insert one of the pipes into the largest artery of the part and securely tie it round, passing the thread over the cross wires so as to prevent the possibility of its slipping off. Then the syringe is to be filled with the injection, the piston being moved up and down two or three times so as to exclude all air. For the same reason, the pipe should be filled with fluid injection before the artery is tied upon it. If air, even in very small quantity, is driven into the vessels, the injection will fail. The syringe being full, its end is to be fitted into the pipe, the stop-cock opened, and the injection thrown in with a gentle, equable pressure on the piston. Should a second syringeful be required, the pipe to which the artery is tied must be plugged with a cork (previously fitted) the instant the syringe is withdrawn; or if the latter has a double stop-cock, the one next the pipe may be shut off, and the syringe, being unscrewed between the

two cocks, is then refilled, and the operation proceeds as before. If the transparent injection is employed, it may be used without heating either the specimen or the fluid.

126. *Muscular fibre.* Muscles are those collections of fleshy fibre by which the motions of the body are produced. Attached to the bones by means of their tendinous extremities, they produce motions of great power by their contractions and relaxations ; and the rapidity with which these effects can be produced is most astonishing to the reflecting mind. Perhaps one of the most remarkable illustrations is the motion of an insect's wing. Every one has doubtless seen them in incessant motion, vibrating at so rapid a rate, that the form of the wing can no longer be distinguished by the eye, moving several thousand times in a minute. Yet, for the production of each upward and downward movement of the wing, two different sets of muscles have to be alternately contracted and relaxed. There are two kinds of muscles, voluntary and involuntary. The first perform those motions which are subject to the action of the will, such as the movements of the hand and foot, &c. The others are not under the control of the will, but proceed in their function without attention from the individual. Such are the muscles which cause the action of the heart and lungs, &c. Muscles may readily be seen to be composed of numerous parallel fibres, running from end to end ; in mutton, pork, or cod, for example, they are visible to the eye. Each of these fibres, is, in like manner, itself a bundle of still more minute fibres, or *fibrillæ*, which are parallel with the fibres' length. Respecting the ultimate structure of these fibrillæ, there is much controversy among microscopists and anatomists ; some asserting them to be composed of cells laid end to end ; others as positively declaring, that each consists of a spiral fibre, inclosed in a membranous sheath. It may be that both are true. Voluntary and involuntary muscles present a different appearance in their fibrillæ ; those of the former are banded with alternately light and dark spaces, those of the latter are more uniform in aspect. The fibres of the pig are among the largest among mammalia. Those of many fishes are also large. Muscular fibre should be mounted in fluid.

127. *Skin.* This we must pass by very cursorily. A perpendicular section through the skin, if carefully prepared, will exhibit under a high power, the glands and minute wriggling tubes through which perspiration is performed. A thin layer of the skin of the negro exhibits its pigment cells, to

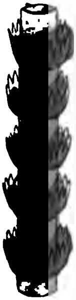
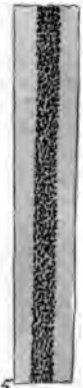


Fig. 44.



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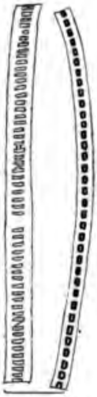

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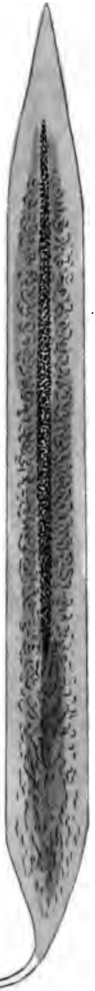
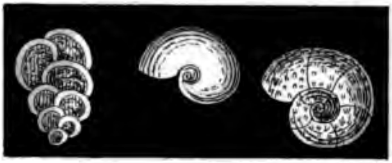


Fig. 4



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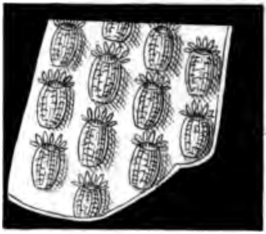

Fig. 49.

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Badger.
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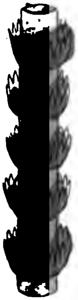
Kangaroo.
Musk rat (Fig. 45).
Chetah.
Civet cat.
Hog-deer.
Persian cat.
Persian sheep.
Sun bear.
Coati mundi.

Corsican deer.
Wapiti deer.
Dormouse.
Field mouse.
Flying squirrel.
Fox.
„ Siberian.
Georgian seal.
Golden agöuti.
Puma.
Polar bear.
Rabbit.
Tiger.

Indian antelope.
Lemur, black.
„ red-fronted.
„ white-fronted.
„ ruffled.
Leopard.
Mangue.
Racoon.
Rat, Indian.
„ kangaroo.
Sable.
Seal.
Vampire bat.



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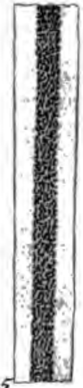

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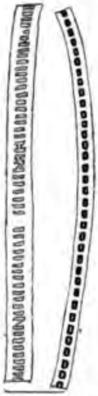

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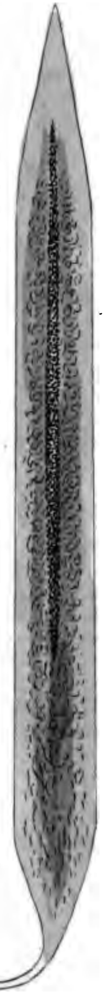

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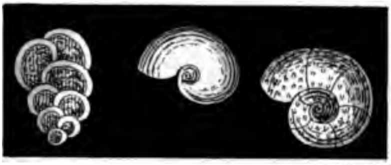

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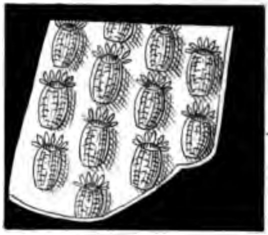

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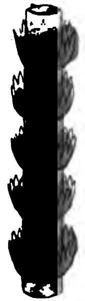

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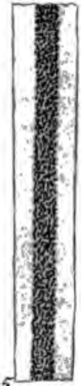

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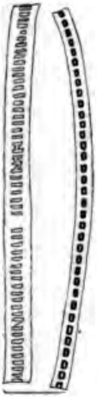

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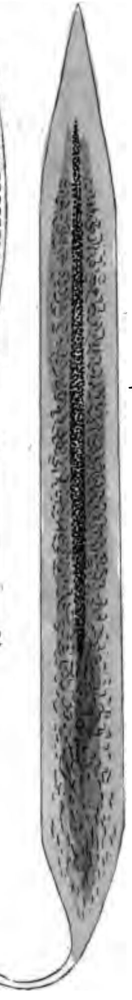

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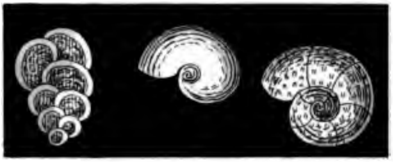

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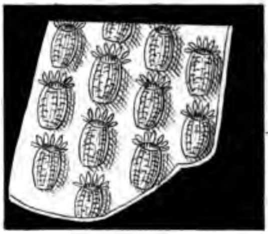

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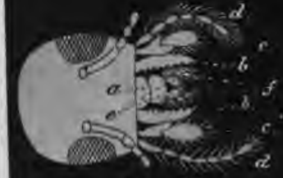


Fig. 35.

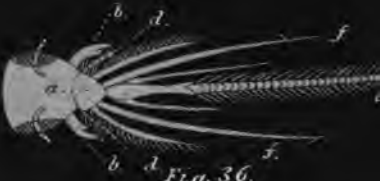


Fig. 36.

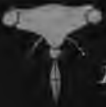


Fig. 37.

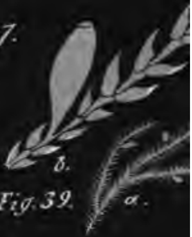


Fig. 39.

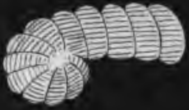


Fig. 38.

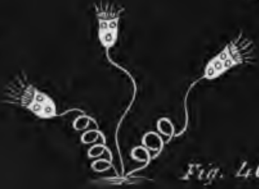
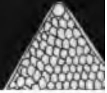


Fig. 40.



vulgarly called horns, composed of a number of small joints placed end to end. Their use is not positively known. By some they are regarded as organs of hearing, and by others as feelers. Their form is very various, and even the male and female of the same species have frequently different antennæ. Those of various beetles of the section *Lamellicornes*, have a knob at the end of their antennæ, which is composed of a series of plates fixed at one end, and free at the other, like the ribs of a fan (Fig. 33). The cockchaffer is an example. These should be spread out before mounting. Most kinds are best exhibited mounted in balsam. The following list contains some of the most interesting examples :—

Agaon paradoxum.
Aphodius.
Ascalaphus.
Carabus.
Cerambyx.
Psychoda ocellaris (midge fly).
Claviger longicornis.
Melolontha vulgaris (common cockchaffer). Antenna with 7 plates.
Rhisotrogus solstitialis (July dor) (Fig. 33) Antenna with 3 plates.
Blatta orientalis (cockroach).
Ctenophora (crane fly).
Diaperis Boleti.
Elater cupreus.
Brachinus.
Calathus.
Harpalus.
Dytiscus.
Forficula (earwig).
Eristalis.
Tipula.
Thrips.
Leucoma salicis.
Mole cricket.
Staphylinus.
Pulex felis (flea of cat).
Odonestis potatoria (drinker moth).
Arctia caja (tiger moth).
Episema ceruleo-cephala (figure of 8 moth).
Clisiocampa neustria (lackey moth).
Porthesia auriflua (brown tail moth).
Fidonea ericetaria (bordered grey moth).
Zeuzera æsculi (wood leopard moth).
Saturnia pavonia major.
(The antennæ of the above 8 should be those of the male insect.)
Philonthus.
Lampyris.
Silpha.
Hydrophilus.
Cetonia.
Curculio.
Culex (various species), gnat.

136. *Mouth apparatus.* This affords numerous objects of exceeding beauty and interest. It is very different in character to the masticating organs of the higher animals, and is composed of several pieces which vary in character and form according to the habits of the insects, and the nature of their food. Among gnawing insects (*Mandibulata*), such as beetles, locusts, cockroaches, &c., the mouth is furnished with a central piece, called the *labrum* or upper lip (Figs. 35, 36, and 37, *a*); on the side of which are a pair of horny jaws, termed *mandibles* (*bb*). Behind these mandibles is a second pair of complicated appendages, called *maxillæ* (*cc*), or secondary jaws. These have on the inside a plate or cylinder of greater or less hardness, generally armed with notches or hairs, and on the outside one or two small appendages composed of several joints, called

maxillary palpi (*d*). Again, behind the maxillæ is found a second pair of appendages, whose base is supported by a central piece, called the *mentum* or chin. These appendages constitute *the tongue* (*e*): the union of the mentum and tongue is called the *labium*, or lower lip, and a second pair of jointed appendages or palpi are called *labial palpi* (*ff*). These will be better understood by comparing the description with figures 35 and 36. The palpi serve chiefly for seizing the food, and holding it between the mandibles while the teeth divide it.

137. These parts are very much modified in different orders and families of insects, according to their habits and kind of food, and method of obtaining it. Thus, among the sucking insects (*Haustellata*), the maxillæ or the upper lip are lengthened so as to form a tubular trunk. Among many of the *Hymenoptera* (Fig. 36,) (bees, &c.), the maxillæ and the tongue are greatly elongated: the former have a tubular form, and inclose longitudinally the sides of the tongue, so that these organs united, form a canal through which they can imbibe their food. With their mandibles they cut the materials for their nests, or seize and put to death their prey. Among the *Hemiptera*, &c., (Fig. 37,) (bugs, cicadæ, &c.), the mouth apparatus is composed of a tubular and cylindrical proboscis, which, when not in use, is bent underneath the thorax: it is composed of a sheath of four joints, representing the lower lips, which incloses four bristles or piercers, which represent the mandibles and maxillæ. Among the flies (*Diptera*) the proboscis is sometimes soft and retractile, at other times horny and lengthened, and is commonly furnished at the end with two lobes or lips, of most curious structure, and each of which is provided internally with very numerous branches of the tracheæ: the setæ or bristles, and which in some insects closely resemble surgical lancets, vary from two to six in number: they represent the same parts. Sometimes the proboscis is of enormous length, in other insects very short. In the butterflies there are no setæ, but the mouth is furnished with a long tubular trunk, composed of two channelled threads adapted face to face, so that a channel is formed by the union of the two grooves; these are the maxillæ thus modified. This trunk is spirally coiled beneath the head when not in use. Such are some of the modifications observable among insects of this part of their structure; and a series of slides, well exhibiting this singular apparatus, and judiciously selected so as to display its peculiarities in the different tribes and families, will form a most attractive and beautiful class of objects, second to none in interest and beauty.

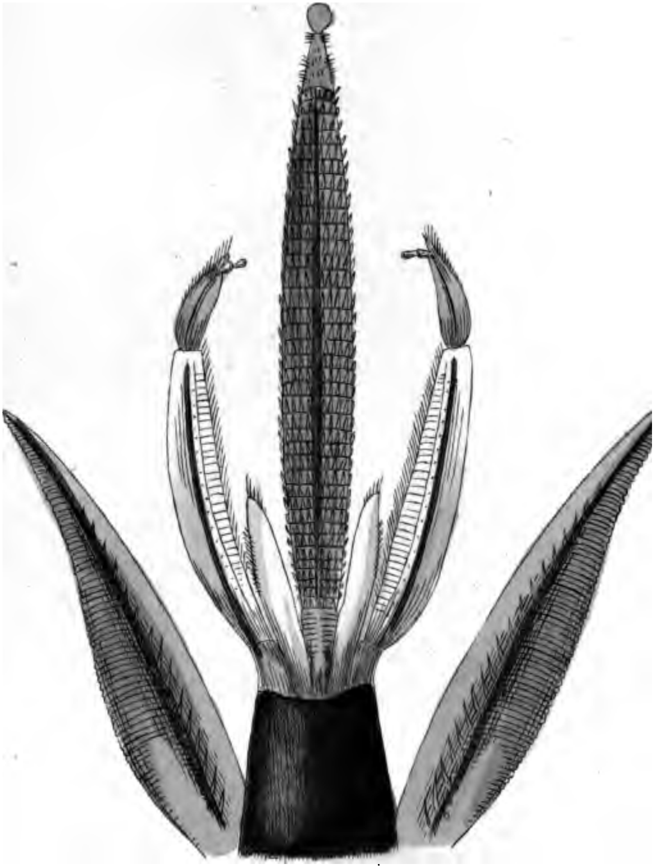


Fig. 56.

138. One very singular appendage to the mouth apparatus may be mentioned here. It will be found in the aquatic larvæ of the insects popularly termed Dragon-flies, and is a modification of the lower lip. It is a kind of mask, composed of several pieces, and covering the maxillæ, mandibles, and nearly all the under side of the head when it is closed together; but it is capable of being extended and unfolded, so as to become the instrument by which it seizes its prey. It forms a very curious object. The following list will point out some of the most interesting varieties; but the field is very vast, and will amply repay those who will investigate it, and can bring time, patience, and some knowledge of entomology to their aid. Most of these objects require to be mounted in balsam.

Aphis quercus.
—— humuli (hop-fly).
Cimex nigricornis.
Hæmatopota pluvialis (cleg).
Tabanus (gad-fly).
Chrysops (ditto.)
Hippobosca equina (forest-fly).
Bembex.
Ammophila sabulosa (sand-wasp).
Vespa vulgaris (common wasp).
Odynerus } solitary wasps.
Eumenes }
Anthophora retusa.
Bombus (humble-bee).
Apis mellifica (hive-bee).
Andræna.
Various species of solitary bees (Fig. 56.)
Cicada.
Vanessa atalanta (red admiral).
Pontia brassicæ (white-cabbage butterfly).
Blatta orientalis (cockroach), palpi.
Notonecta (boat-fly), internal setæ.
Acilius.
Larva of Ephemera.
Musca vomitoria (meat-fly).
—— Cæsar (blue-bottle fly).
—— pendula.
—— domestica (common fly) (Fig. 57).
Sarcophaga carnaria (blow-fly).
Stomoxys calcitrans.
Pulex irritans (flea).
Empis.
Dioctria.
Culex pipiens (gnat).
Panorpa (scorpion-fly).
Rhingia.
—— rostrata.
Hydrometra.
Scatophaga.
Gonepteryx rhamni (brimstone-butterfly).

139. *Eyes.* These are among the greatest marvels of the insect world. The eyes of insects are often very large in proportion to the size of their bodies, and, unlike those of the higher animals, are immovable. Fixed to either side of the head, and projecting thence like a semi-globular tumour, they present to the naked eye a very dull appearance. But on viewing them even with a lens of low power, it is seen that they are formed like a multiplying glass, being composed of great numbers of hexagonal facets; and minute and delicate dissection has revealed the fact, that every one of these facets is a separate and perfect lens, fixed at the broad end of a tube, the narrow extremity of which is terminated by a filament of the optic nerve, and which, by inclosing membranes and a layer of pigment, is completely isolated from each adjoining eye. All

these filaments of nerve terminate in a large bulbous expansion of the optic nerve, which fills up a large portion of the hemisphere. The great multiplication of the lenses of the insect eye, and its very convex form, make up for its fixed character. There is no reason for supposing that the insect perceives more than one image of the object, any more than, though possessing two eyes, in each of which, of course, an image is formed, we perceive but one. Of the mechanism of vision among insects, however, little or nothing is known ; all that we can say with certainty is, that it is remarkably acute and perfect.

140. That each facet of these compound eyes is a distinct and perfect optical instrument in itself, may be proved by viewing a properly mounted insect's eye under the microscope. The mirror should be removed, and the microscope being brought into a horizontal position, and the object placed a little beyond the focus, a perfect image of any object placed before the eye will be seen accurately depicted in every separate lens. The sheet of lenses may be easily separated from the other parts of the eye by maceration for some time in water. In most compound eyes these lenses are wonderfully numerous. The eye of the house-fly possesses about 4000 separate facets ; that of one of the dragon-flies, 12,000 ; the goat-moth (Cossus), 11,300 ; one of the hawk-moths (Sphinx), 20,000 ; and in a species of beetle (Mordella), upwards of 25,000. To mount the eyes of insects as transparent objects, the layer of lenses must first be separated by maceration, as directed above : the object should then be laid between two dry glasses, which are then to be tightly tied together, and it must remain so till dry, or it is liable to split. They may be mounted dry, in fluid, or in balsam. It may also be well to mount a few, *in situ*, on their respective heads, as opaque objects. The following list will give ample variety :—

Æshna.
Acrocinus.
Agrion ; dragon-fly.
Ant.
Argyronecta.
Cockchaffer.
Mole-cricket.
Cricket.
Dynastes.
Mordella.
Tabanus.
Cimex.
Flea.
Gyrinus.
Sphasus Indianus.
Wasp.
Larva Hydrophilus.
—— Tussock-moth.
Bee.
Beetle.
Black-beetle.
Butterfly.
Cerambyx.
Cockroach.
Scarabeus.
Ctenus dubius.
Dolomedes.
Nepa.
Dytiscus.
—— Larva.
Gnat.
Panorpa.
Hawk-moth.
House-fly.
Locust.
Mantis.
Bombardier-beetle.
Boat-fly.
Buprestis.
Cicada.
Cicindela.
Menelaus.

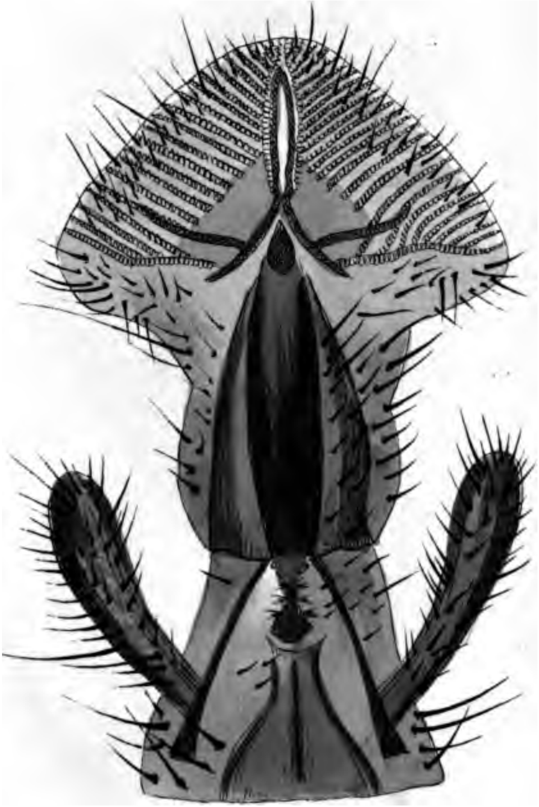


Fig. 57.

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Stomoxys.
Curculio.
Dysdera.
Silpha.
Earwig.
Ephemera.
Grasshopper.
Papilio.
Hydrometra.
Ichneumon.
Peach-fly.
Cossus ligniperda.

141. *Wings.* We need do little more under this head than give a list of those best adapted for examination. The wings of insects are generally transparent, consisting of a framework of hollow and firm nervures or ribs, branching in various directions, and covered with a double membrane. Some wings are beautifully dotted over with minute hairs, as in many flies, and the midge has the ribs elegantly fringed. The wing of *Asilus crabroniformis* is worth examination, as it well displays, when mounted in balsam, the hollow structure of the ribs. Those of the *Phryganea,* or caddis-fly, are often covered with stout hairs or bristles, and the base of these, as well as the minute openings or pores along the ribs, are worthy of attentive examination. In the *Lepidoptera* (butterflies and moths), the wings are covered with a fine mealy dust, as it appears to the naked eye ; but which is in reality a multitude of scales beautifully engraved. The eye-like spot on the wing of the emperor moth shows a concentric arrangement of the scales, and may be mounted in Canada balsam. Wings of very small moths, or small portions of any of the darker-winged butterflies, may be similarly mounted to display the ordinary arrangement of the scales. A very beautiful wing is that of the *Pterophorus,* or plumed moth ; it is composed of nerves or rays, which are entirely unconnected, but are most beautifully fringed at the edge, so as to resemble feathers. These moths are of small size. The hind wings of the *Hymenoptera* (bees, wasps, &c.) present a curious structure in a series of minute hooks (Fig. 54), with which the front edge of the wing is fringed. Their object is to clasp the hinder part of the front wing while flying, so as to increase their strength of flight. The following are some of the best wings for mounting :—

Acrida viridis.
Calepteryx.
Cicada.
Ægeria tipuli.
Cercopis.
Cimex.
Buprestis.
Thrips.
Chrysis.
Coryxa.
Humble-bee; for hooks.
Cydnus.
Ephemera.
Hemerobius.
Ladybird.
Wasp (Fig. 54).
Mantis.
May-fly.
Phryganea.
Trichiosoma.
Cynips.
Gnat.
Idephorus.
Hornet.
Lanthorn-fly,
Midge-fly.
Notonecta.
Plumed moth.
Urania leilus.
Earwig.
Grasshopper.
Ichneumon.
Leptocerus.
Menelaus.
Panorpa,
Tenthredo.
Thais Cerisyi.

142. *Elytra.* The *Coleopterous* insects (beetles and their allies) have, instead of the front pair of wings, a pair of hard, horny wing-cases, or *elytra*, which, when the insect is at rest, cover the back, concealing beneath them the fine membranous wings. In some insects these wing-cases are singularly engraved and coloured. In some they are plentifully beset with splendid scales; in others they are sprinkled with dots, and others are furnished with branched hairs. When elytra are to be mounted as transparent objects, they must first be softened in solution of caustic potash. The elytron of the diamond beetle, one of the most magnificent of microscopic objects, may be mounted in Canada balsam, and viewed as an opaque object. The following deserve attention:—

Bronze-beetle.
Buprestis.
Cantharis.
Carabus.
Unicorn-beetle.
Flame-beetle.
Gyrinus.
Pupa of Agrion.
Chrysis.
Chrysomela.
Cicada.
Cicindela.
Dytiscus.
Golden-beetle.
Musk-beetle.
Rose-beetle.
Corixa.
Curculio.
Dermestes.
Diamond-beetle.
Elaphus.
Stenus.
Notonecta.
Cercopis sanguinolenta.
Under membrane of Elytron of Cockchaffer.

143. *Scales.* The objects to be enumerated under this head will not, probably, excite the wonder and admiration of the unscientific observer so much as some of those already described; but they are, nevertheless, replete with interest. Four orders of insects afford them: the *Lepidoptera*, *Coleoptera*, *Diptera*, and *Thysanoura*. The *Lepidoptera* (butterflies and moths) are so called because their wings are covered with scales (*lepis*, a scale, and *pteron*, a wing—Greek). Every one must have observed, that on handling the wing of one of these insects, the finger removes from it with the greatest readiness a mealy dust or powder. Under the microscope this dust is seen to be a multitude of scales (Fig. 34), each of which is furnished with a projecting point by which it is inserted into the wing, on which they lie overlapping one another, like the tiles on the roof of a house. Submitted to an achromatic lens of good power, these scales are seen to be ruled with delicate, parallel, longitudinal lines. The variety observable in the scales of the *Lepidoptera* is not great. The usual form varies from the longest strap-shaped scale to one broader than it is long, but nearly all toothed or jagged at the outer end. These, and all intermediate varieties, may be found on almost every butterfly and moth. The scales of the large male cabbage-butterfly (*Pontia brassicæ*) are very peculiar and interesting.

They are long and strap-shaped in form, inserted by their narrow end into the wing by a bundle of rootlets ; at the opposite or outer end, is a rounded notch, from the bottom of which hangs pendant by a cord a small black tassel. The peculiar character of the lines in this scale, and the difficulty with which they are seen, makes it valuable as a test object. A similar scale, but shorter and broader, and on which the lines are more easily discernible, is that of the *Pontia rapæ* (the male insect). Another very interesting scale is that of the blue argus butterfly (*Polyommatus argus.*) The wings of this butterfly are furnished with two totally different kinds of scales,—one kind is like those ordinarily found on the wings of butterflies, &c. ; the others (Fig. 34, *b*) are only found on the under side of the wing, and resemble in shape a child's battledore ; and on the surface of the oval portion four or five rows of black spots are visible under an achromatic lens. With a very superior lens of high power, these spots appear to be clusters of spines. These are the most remarkable varieties ; but scales from the wings of any of the insects mentioned in the following list, will be found worthy of mounting :—

Papilio Machaon (swallow tail).
—— Cethosia.
—— Idas.
—— Paris.
Pontia brassicæ (cabbage butterfly).
—— Rapæ (small white do.) (Fig. 51).
Doritis Apollo.
Vanessa Io (peacock butterfly).
—— erythrya.
Apatura Iris (purple emperor).
Morpho Menelaus.
Pieris euchoris.
Polyommatus acis (mazarine blue).
—— Argus (silver-studded blue) (Fig. 34).
—— Adonis (Clifden blue).
—— Alexis (common blue).
Lasiocampa quercus (oak egger).
Urania leilus.
Tinea vestianella (clothes' moth).
Saturnia pavonia minor (emperor).
Dasychira pudibunda (pale tussock).
Cithoria julia.
Adela de Geerella (long-horned moth).
Cerura vinula (puss moth).
Sphinx ligustri (privet moth).
Cossus ligniperda (goat moth).
Alucita hexadactyla (20-plume moth).
Pterophorus pentadactylus (white plume).
Anthrocera filipendula (6-spot Burnet) (Fig. 52) from underwing.
Phalæna grossulariata (magpie moth).
Bombyx mori (silk-worm moth).
Arctia caja (tiger moth).
Culex pipiens (gnat).
Hipparchia janira (meadow brown).
Lycæna phæas (copper butterfly).
Mamestra persicariæ (dot moth).
Achronycta psi (dagger moth).
Plusia iota (golden Y), from white spot.
Catocala nupta (red underwing).
Ino statices (green forester).
Cyphys gemiri.
Euplœa limniacea.

144. A few of the *Coleoptera* have scales. Those of the diamond beetle (*Curculio imperialis*) are especially splendid, reflecting from their grooved surfaces the colours of the emerald, ruby, and sapphire ; and so dazzling is their radiance, that it is said that the eye is unable to bear their brilliancy as they fly in swarms in the bright sunlight in Brazil. The head,

wing-cases, and legs are studded with these scales, which, viewed as transparent objects, are found to be richly mottled with various colours, and lined like those of the *Lepidoptera*. The small scales from the legs are considered good test objects, as the lines on them are only to be seen with a good instrument, and with the most careful attention to the focus and illumination. The oak *Curculio*, a native of this country, is in many respects equal in beauty, as an object, to the diamond beetle.

Many insects of the order *Thysanoura* possess scales which attract the attention of every microscopist. The insects belonging to this order have no wings, but the abdomen is furnished with false legs or appendages, adapted for leaping. The scales of two insects of this order, *Lepisma saccharina* and *Podura plumbea*, are especially valued as test objects, as the distinctness with which their minute and curious structure may be seen, varies with the degree of excellence of the instruments. The *Lepisma saccharina*, or sugar-louse, is a silvery-looking insect which frequents closets, book-shelves, &c. The *Podura plumbea* is a small flea-like insect, which inhabits damp places, and is very frequent among the damp sawdust of wine-vaults, and, though very nimble, may be caught by the following plan :—Sprinkle a little oatmeal or flour on a piece of black paper, and place it near their haunts; after leaving it for a few hours in the dark, the paper must be carefully placed in a large glazed basin, so that when they leap from the paper, on being brought into the light, they may fall into the basin, and separate themselves from the bait. The scales must be detached with extreme care, because the insect is soft and easily wounded, and the fluid which exudes from any puncture adheres to the scales, and obliterates their markings. Other species of the genus are found in damp places, under decaying bark or vegetable refuse. A very small species (*Podura aquatica*) may often be seen in shoals upon the rain water collected in the footsteps of cattle, the ruts of cart-wheels, or by the edges of small ponds, looking precisely as if the water had been strewed with gunpowder or coal dust. Another insect of the same tribe, *Petrobius maritimus*, is found under stones near the sea-coast, and possesses interesting scales.

145. *Hairs.* These need no explanations, and therefore, we shall only point out a few of the most interesting examples. The hairs at the tail of the larva of the *Dermestes* possess a very curious structure, which renders them good test objects.

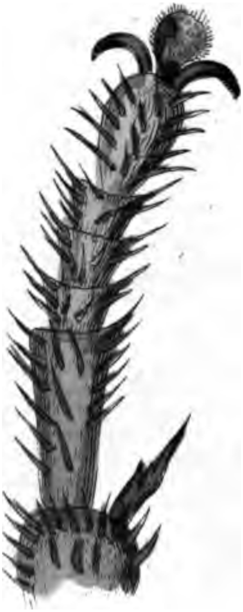


Fig. 58.

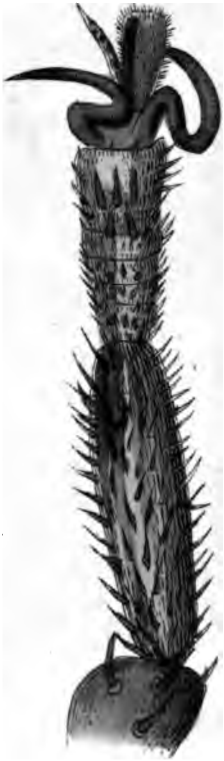


Fig. 59.

Under an achromatic lens of low power, each hair appears to be composed of a number of conical joints, surmounted by a very curious helmet-shaped head; but under a superior lens of high power, each joint is found to be a whorl of close-set spines; and the helmet-like extremity appears also to be composed of large spines.

Hair of larva of Dermestes.
,, Stag-beetle.
,, Larva of tussock-moth.
,, Acilius canaliculatus.

Hair: Wing of Tipula.
,, Indian-bee.
,, Bee.
,, Eucera longicornis.
,, Melecta punctata.

146. *Legs and Feet.* Among these we shall find some curious objects, well worthy of attentive examination. Caterpillars are provided with two distinct kinds of feet. The true legs, six in number, are short and armed with a claw; the others, called *pro-legs*, are also short, thick, and so constructed as to act as a sucker to aid in retaining a firm hold. To give still further facility for strong adhesion, the circular edge of the extremity of the foot is fringed with a row of powerful hooks. These pro-legs, mounted so as to show the hooks, are interesting objects. The feet of various kinds of flies, mounted so as to show the pads or "suction" apparatus (*pulvilli*), by means of which they can walk in an inverted position, or up a pane of glass, are well worthy of examination. We say "suction," because it has long been supposed that flies walk in these positions by creating a vacuum, so that the pressure of the air sustains the weight of their bodies; but some recent observations would lead to the supposition that these pads emit a viscid fluid, by the adhesion of which the body of the fly is sustained against the force of gravity. In some species there are two *pulvilli*, in others three. The male *Dytiscus* has a curious disk on the inside of each of the four front legs, which is an admirable object mounted in balsam. By means of it, it seizes and detains its mate. The oar, or long leg of the boat-fly, is also worth mounting.

Acilius canaliculatus.
Carabus monilis.
Curculio.
Diamond beetle.
Common fly.
Dung-fly.
Hippobosca equina (forest-fly) (Fig. 59).
Chrysis.
Hind-leg of neuter honey-bee.
Cimbex lutea.
Dioctria.
Hydaticus transversus.
Hydrachna.

Dytiscus circumflexus.
—— dimidiatus.
—— marginalis.
Mellinus arvensis (Fig. 58).
Cerceris arenaria.
Ammophila sabulosa.
Vespa vulgaris (wasp).
Rhagium.
Notonecta.
Smerinthus ocellatus.
Pro-leg: Larva of Cossus (fig. 31).
,, ,, Tussock moth.
,, ,, Privet moth.

147. We now come to notice some portions of the internal structure of insects. We begin with the respiratory system. This presents striking peculiarities. The vertebrate animals breathe either by lungs or gills; but insects have neither, and yet their breathing apparatus is singularly perfect, and adapted for their habits, requirements, and organization. If any one will carefully examine a caterpillar (of the goat-moth, for example), a row of spots may easily be detected on each side of its body, there being generally one of these spots on each side of each segment of the body, one or two excepted. If one of these be dissected off a dead specimen, and examined under the microscope, it will be seen to be oval in form, with a thickened border, and a slit from end to end through the middle. From the circumference to either edge of the opening, muscles may be detected, which serve to enlarge or contract the orifice at will. These are called *spiracles*, and are the openings through which air is admitted to the body. *Internally* they open into the *tracheæ*. These are two tubes, large in proportion to the size of the insect, which run on either side of the body, from end to end, or nearly so; on the side next the skin they communicate by short tubes with the spiracles; and, on their other sides, send off branches, which ramify in all directions through the body, much after the manner of the arteries of the higher orders. These tracheæ and spiracles remarkably resemble in structure the stomata and spiral vessels of plants. They are composed of two membranous tubes, fitting close within one another, and containing between them a closely coiled cartilaginous spiral fibre. In some of the larger tracheæ the coils of this fibre give the vessel the appearance of a piece of richly watered silk.

148. To understand their office, we must take into consideration the peculiarities of the circulation of insects. In the higher animals the blood, as it returns by the veins to the heart, is conveyed by the pulmonary artery to the lungs, to be aërated ere it is again sent into the arteries in general to assist in the maintenance of the functions of the body; and this aëration of the blood is thus accomplished. The bronchial tubes, by which air is inhaled into the lungs, divide and subdivide into countless branches, each of which terminates in an air-cell. On the walls of these air-cells the capillary vessels, into which the pulmonary artery also subdivides, are thickly convoluted, so as to present to the largest possible surface of air, the blood, also spread over so large a surface that every blood disk in its turn is presented to the air, only divided

from it by a thin membrane which the air can permeate. Having parted with the impure gases with which it is laden, the blood returns, charged with a fresh supply of oxygen, back to the heart, to be again thrown into the general circulation. An insect, however, has neither heart, arteries, veins, nor red blood, and its circulation is what is termed a diffused one ; there being apparently no vessels, strictly speaking, in or through which it is carried on. A long tube, with several chambers, lying under the back, is called the *dorsal vessel*, and appears to have an office *somewhat* analogous to the heart. The circulating fluid or blood, which is white, is received by openings in the side and end of the dorsal vessel, and is forced onwards by the successive contractions of the different chambers, till it passes out by a number of canals which convey it onwards to the head and other parts of the body. It does not, however, circulate throughout the body in vessels, but appears to penetrate among the interstices between distinct organs, or through the cavities of their tissues. It thus comes into close contact in all directions with the ramifications of the tracheæ, and so becomes aërated and fitted for continued circulation.

149. Spiracles may be found in almost every insect ; those mentioned below afford good specimens and interesting varieties, and are easily attainable. They may be mounted in balsam. That of the perfect beetle of the *Dytiscus* is very curious. Many aquatic larvæ have no spiracles, but breathe through their tails, which may often be observed at the surface of the water while their heads are downwards. The larva of a species of *Libellula* (dragon-fly) possesses three plates at the tail, in shape like the oval leaf of a plant, and the tracheæ, with their numerous branches, may in these be readily seen. These leaflet-tails are beautiful objects mounted in balsam. Tracheæ may be readily obtained by dissection, and Mr. Quekett has given a very simple process for obtaining the entire respiratory system perfect. Make a small opening in the body of the larva, and then place it in strong acetic acid. This will soften or decompose all the viscera, and the tracheæ may then be well washed with the syringe and removed from the body with the greatest facility, by cutting away the connexions of the main tubes with the spiracles by means of fine-pointed scissors. Put the slide into the fluid, float the tracheæ upon it ; arrange and dry them, and finally mount them in balsam.

SPIRACLES.

Larva: Cossus ligniperda (Fig. 32). (Goat moth.)
Larva: Melolontha (Cockchaffer).
Larva: Fly.

Larva: Privet moth.
Acilius.
Dytiscus marginalis. (Perfect insect.)

TRACHEÆ.

Larva: Dytiscus.
,, Hydrophilus.
,, Rhinoceros beet
Nepa cinerea.

OTHER RESPIRATORY APPARATUS.

Ephemera vulgata (pupa), *May-fly*. Gills on side of abdomen.
,, ,, ,, tail.
,, gills of pupæ of various other species.
Agrion (larva) terminal plates of tail.
Stratiomys chameleon (larva). Breathing apparatus of tail.

150. *Circulating system.* Having above briefly explain
the nature of the circulation in insects, we need here or
point out some objects in which (of course *living*) it may
observed. The following are all aquatic:—

Larva of Ephemera.
,, Hydrophilus.
,, Dytiscus (small).

Larva of Agrion puella.
,, Libellula.

151. *Digestive apparatus.* This has generally a very co
plex structure. Comparing it with that of the higher ord
of animals, the following parts may be distinguished in
commencing with those next the mouth. First is the *phary*
then the *œsophagus* or throat; the first stomach or *crop*; th
a second stomach or *gizzard*, which is armed with horny p
cesses or spines for grinding the food, which then passes in
the third stomach, where it is digested. This stomach is u
ally furnished with numerous *villi* or velvety hair-like proj
tions, which are supposed to secrete the gastric juice. Bel
this stomach are the intestines, the cæcum, and rectum. E
cept to the practised dissector and microscopist, the digesti
system of insects will afford but little, inasmuch as it requi
very delicate manipulation, a large amount of practice, sk
and patience to free it from its connexions, and display it
anything like a perfect state. The gizzard, however, is a ve
interesting object, and is easily prepared. That of the cricket
a favourite subject, and has more than 200 strong horny tee
Those of the locust and grasshopper are also interesting.

152. *Ovipositors and stings.* The abdomen of insects
composed of a series of rings so united to each other as
form a very firm protection, yet capable of a consideral
amount of motion and retraction. The last segments of t
abdomen are in some insects furnished with certain app
dages, which can be protruded or retracted by the insect

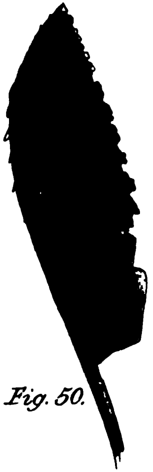


Fig. 50.

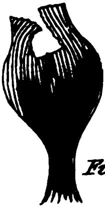
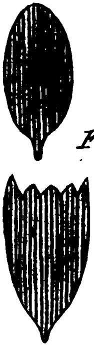


Fig. 51.



Fig

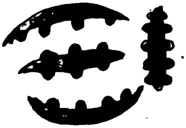


Fig. 53.

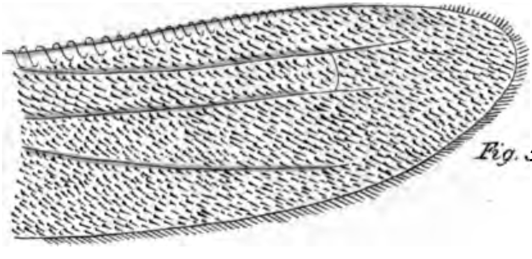


Fig. 54.

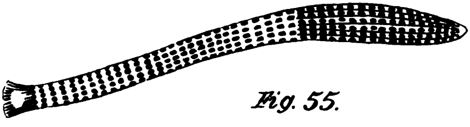


Fig. 55.

pleasure, being furnished with powerful muscles for the purpose. In some insects these appendages are termed stings, being composed of a hollow tube, furnished with sharp piercers within, and connected at the base with small glands which secrete a poisonous fluid, which is injected through the sting when a puncture has been made. Other appendages have a more harmless office; being usually *ovipositors*, or instruments wherewith to assist in depositing the eggs, or to assist in preparing a suitable place of deposit for them. Such are the saws of the saw-fly (*Tenthredo*), which afford very curious objects. Some of these appendages are not retractile, but are affixed exteriorly to the end of the abdomen. Some ovipositors are so; so are the forceps of the earwig, and the springs of the *Poduridæ*. The drum of the cicada is a very curious organ, situate between the belly and hind-legs. There is a pair of these drums in each male insect, one being on each side. They are employed for producing the sounds for which these insects are famous. The grasshoppers and crickets possess a somewhat similar organ.

STINGS.
Bee.
Wild bee.
Hornet.
Sphex.
Wasp.

OVIPOSITORS.
Cicada.
Cynips quercus.
Ichneumon.
Tipula.
Tenthredo
Trichiosoma
Cimbex
Nematus
Hylotoma
} saw-flies. (Fig. 50).
Urocerus.
Oryssus.
Drone fly.
Field cricket.

SUNDRY.
Drum, cricket.
File, grasshopper.
,, cricket.
Forceps, earwig.
Poisers, crane fly.
Rectum: Æsbna grandis.

153. The eggs of insects afford a vast variety of forms, often richly and elaborately sculptured. They must be mounted in fluid, in a cell (see sect. 38).

The following are specially interesting:—

Pontia Napi.
Vanessa urticæ; small tortoiseshell butterfly.
Hipparchia tithonus.
—— furtina.
Argynnis lathonia.
Cerura vinula; puss moth.
Sphinx Ligustri; privet moth.
Rumia Cratægata; brimstone moth.
Hipparchia janira; meadow brown.
Bombyx mori; silkworm moth.
Blatta orientalis; cockroach.
Acheta campestris; field cricket.
Nepa ranatra; water scorpion.
Cimex lectularius; bug.
Scatophaga stercoraria; cowdung fly.
Musca vomitoria; blow fly.
Pulex irritans; flea.
Pygæra bucephala; buff tip moth.
Clisiocampa neustria; lackey moth.
Noctua nupta.

154. *Entire Insects.* We can here only point out a very few, and may state, that numbers more of the minuter species may be mounted similarly, with whose names we are unac-

quainted. Most of these may be mounted in Canada balsam, after having been carefully pressed and dried between slips of glass.

Bug.
Cimex flavicornis.
Black ant.
Ploa minutissima.
Curculio (thistle) opaque.
Flea, common.
Flea of mole.
Aphis (plant lice), various species.
Tipula tritici.
Termes pulsator.
Curculio oak (opaque).
„ nettle, „
Cynips oak, „
„ rose.
„ dog-rose.
Mymar pulchellus.

For a considerable portion of the preceding lists of insect objects, as well as for some few of the details, we are indebted to Mr. Pritchard's *Microscopic Objects.* For extended details, we may refer to Mr. Westwood's *Entomologist's Text-Book,* and for descriptions of the British genera, to the same author's *Introduction to the Modern Classification of Insects,* at the end of vol. ii.

155. Ere we pass from the insects, we must notice one order, the species of which are always mounted entire. This is the order *Anoplura,* which is distinguished by the absence of the compound eyes, by their undergoing no metamorphosis, having no wings, the legs short, and terminated either by a nail, or by two opposing hooks. The insects of this tribe are, in ordinary language, called *lice,* and the number of species is very considerable ; very many mammals and birds having species peculiar to themselves infesting them. Notwithstanding the disgust which their vulgar name inspires, they will be found to present many objects of beauty and interest, they being often richly coloured. That parasitical on the turkey, is one of the most beautiful. They are most readily obtained in the spring. With the view of aiding the microscopist in their acquirement, we give a list of the most frequent and interesting species, and of the animals on which they are to be found, appending figures to denote their frequency of occurrence ; and for full details and figures of all the British kinds, we refer the reader to Denny's *Monographia Anoplurorum Britanniæ.* 1 denotes, not common ; 2, frequent ; 3, common ; 4, very common.

		Found on the
1	Hæmatopinus spinulosus,..	Rat.
1	—— piliferus, ...	Dog.
4	—— eurysternus, ...	Ox.
4	—— asini, ...	Ass, on the mane and back.
3	—— suis, ...	Pig, on lean animals, especially on Irish pigs.
4	Docophorus atratus, ...	Rook.
2	—— communis, ...	Bunting, bullfinch, nuthatch, sparrow, &c.
3	—— *leontodon,*	Starling.

3	Docophorus ostralegi,	Oyster catcher.
2	—— Turdi,	Thrush.
2	—— aquilinus,	Golden and white-tailed eagles.
2	—— humeralis,	Curlew, common; gannet, whimbrel, and foolish guillemot, sparingly.
3	—— lari,	All gulls.
3	—— latifrons,	Cuckoo.
4	—— icterodes,	Common on ducks.
3	Nirmus cameratus,	Red and black grouse.
3	—— gracilis,	House marten.
2	—— argulus,	Rook.
2	—— attenuatus,	Corncrake.
1	—— junceus,	Lapwing.
3	—— tenuis,	Sand marten.
4	Goniocotes compar,	Common on pigeons.
2	—— hologaster,	Common fowl.
3	Goniodes falcicornis,	Peacock, especially about the base of the beak, and crown of the head.
4	—— stylifer,	Turkey.
3	—— colchici,	Pheasant.
3	—— tetraonis,	Red and black grouse.
4	Lipeurus variabilis,	Domestic fowl, on primary and secondary feathers of the wings.
4	—— stylifer,	Turkey, wing feathers.
4	—— baculus,	Pigeon.
4	Trichodectes crassus,	Badger.
4	—— latus,	Dogs, especially puppies.
4	—— scalaris,	Cattle, frequenting the mane.
4	—— equi,	Horse and ass, especially when fresh from pasture.
3	—— longicornus,	Fallow-deer, on the inner side of the thigh.
2	Colpocephalum flavescens,	On various species of the genus *Falco*.
4	—— subæquale,	Rook.
3	—— eurysternum,	Magpie.
2	—— importunum,	Heron.
4	Menopon pallidum,	Common fowl.
3	—— troglodyti,	Common wren.
3	—— perdicis,	Partridge.
3	Nitschia Burmeisteri,	Swift.
4	Trinoton conspurcatum,	Goose.

All the above are worthy of acquisition as microscopic objects. It will be observed, that some birds, &c., are the habitations of more than one species. All the *Anoplura* may be mounted in balsam, being first pressed flat, and dried between plates of glass.

156. Next in order to the insects is the class *Arachnida*, which comprehends the spiders, mites, and scorpions. They are distinguished from insects by the possession of eight legs, instead of six, and by having a number of simple eyes, or *ocelli*, instead of the true compound eyes, which characterize most insects. The microscopic objects which the *Arachnida* afford may be briefly indicated.

The structure of the jaws of various species of spiders, may be very well displayed by mounting their exuviæ, or cast skins, which these animals frequently throw off during the process of growth. The palpi of many species are also well worthy of being mounted, and will afford some beautiful objects. The exuviæ will also enable the variations in the form of the feet to be observed. The claws, by which the feet are terminated, are often toothed like a comb on their inner edge. Some foreign species have hairs of a remarkable structure. The most worthy of note is the *Mygale aviculare,* a bird-catching spider of South America. Hairs taken from the palpi are branched, and have the centre shaft enlarged, fluted, and of a fine orange colour towards the extremity. The spinnerets also deserve investigation. With these the spider forms its web. They are a number of teats, usually five or six, placed on the under and hinder part of the abdomen, and surrounded by a circle. Each of these teats is thickly studded with pores, which are said to exceed a thousand in number upon each teat. Through these pores the gummy fluid is exuded, which, when dried and extended, forms the web ; and each thread of the web being formed of a vast number of the pore-filaments woven together, is much stronger than it would be if formed only of a single cord.

157. *Acaridæ or Mites.* This is an extensive family belonging to the same class, constituting the larger portion of the second division—viz., the Arachnida *breathing through tracheæ or air tubes.* It chiefly consists of very minute animals, which multiply with great rapidity, and are very widely distributed. They seem, to a great extent, to have been neglected by microscopists ; but they will amply repay research, for very many curious forms are to be found parasitic on birds, in damp places, under bark, &c. The species of *Gamasus* live on birds and quadrupeds. Many are very curious. A few reside on the leaves of plants—the elm, for example. Those of the genus *Oribata* live on stones, trees, and moss, and walk slowly. Those of *Uropoda* attach themselves to the bodies of beetles, which are sometimes covered with them. Several species of *Acarus* are common. One (*Acarus scabiei*) is the well-known mite causing the disease known as the "itch." Another (*A. domesticus*) is the cheese mite, found also on dry or smoked meat. Another (*A. farinæ*) is common in flour which has been kept some time. Another (*A. saccharinum*) is found in brown sugar. Out of 36 specimens of brown sugar purchased in the shops of London for the Lancet "*Analytical* Sanitary Commission," and examined by them,

35 were found to contain these mites. *Acarus tellarius* is the red spider of hot-houses, a well-known pest to the gardener. *A. passerinum* is a curious species found on the sparrow. The species of *Bdella* are found under stones, the bark of trees, or in moss. Those of *Smaridia* and *Ixodes* are the ticks which infest the skins of the *Mammalia*, such as the sheep, ox, pole-cat, horse, dog, &c. The structure of the sucker of the ticks is well worthy of the most careful examination. They also frequent thick woods, hooking themselves to plants of no great elevation by their two fore feet. After sucking the blood of animals, though at first small and flat, they swell like a bladder, and attain a large size. *Argas columbæ* infests pigeons, and sucks their blood. The other species of *Argas* are also found on birds. The *Microphothira* are all parasitic. *Trombidium autumnale* is the harvest bug, and is very common in the autumn on grass or other herbage, and insinuates itself into the skin at the roots of the hair, producing a very painful irritation. It is, however, a beautiful object, being of a bright scarlet colour, and may easily be obtained by tying a white pocket handkerchief round the lower part of the leg, and walking through a stubble field; the harvest bugs will attach themselves to the handkerchief, and may be picked off. The species of *Aclysia* live on the *Dytiscus*, a water beetle. Very many species of the *Acaridæ* may be found in every part of the globe. Some of the tropical species are splendid objects.

158. *Crustacea.* This class comprehends the crab, lobster, shrimp, prawn, and allied animals, but affords comparatively few objects of much interest to the microscopist. The shell, or hard calcareous external covering, affords an interesting object in the crab, lobster, &c., if so filed away that only a thin section is left of the external surface; the cells in which the colouring matter is deposited are then distinctly seen, and form a pleasing object for a low power. The eyes of the more perfect animals of this class are compound, like those of insects, but are usually mounted on foot-stalks; and the lenses of which they are composed are square instead of being hexagonal. A low power is sufficient for them. The hairs from the antenna of the crab are also worth mounting. One section of this class, however, the *Entomostraca*, demand a more special notice, as they come peculiarly within the province of the microscopist from their minuteness and variety. They are distinguished from the rest of the order by their possessing no branchiæ or gills, and some have no substitute

for them, though some, on the other hand, have on the fore-legs a kind of respiratory apparatus. They have usually but one eye. Some of the *Entomostraca* have the body inclosed in a bivalve shell, while others have a horny, and others a soft covering. They are almost all minute, and many of the species are very abundantly distributed. As permanent objects, they can only be mounted in fluid; it is as living objects that they are chiefly interesting. Many species may be found by every one. They are all aquatic, and are for the most part inhabitants of fresh water; and during the spring, summer, and autumn, there is scarcely a pool in which some species are not to be found. A brief sketch of the order is all that we can give here, and for detailed information as to the species, their structure, haunts, habits, propagation, &c., we refer the reader to Dr. Baird's *Natural History of the British Entomostraca*, published by the Ray Society.

159. The first and second sections of this order are distinguished from the remainder by possessing branchial or respiratory appendages on their feet. The first section (*Phyllopoda*) consists of animals possessing leaf-like feet. There are but one or two species in this country which are interesting as microscopic objects. The *Artemia salina*, or brine shrimp, is one of these. It has curious gill-like feet, varying in number from two to eleven pairs, according to its age. It is commonly found in the salt-pans at Lymington. Another, the *Branchipus*, or *Chirocephalus*, is often found in great numbers in small pools, especially after heavy rain; the eggs, which are inclosed in a strong shell, seeming to have been transported by the wind. Cart-ruts on the edges of woods or plantations, and even the hollows upon stones, often abound with these curious crustaceans, which are sometimes of a rich colour, and are the most beautiful of the order. It is often to be found on Blackheath. The next section of the tribe (*Cladocera*) consists of similar animals, but inclosed in a bivalve shell. These are chiefly of the genus *Daphnia*, commonly termed water-fleas. The common species, *Daphnia pulex*, is a very interesting object. It possesses a single compound eye, and beautifully branched antennæ. The feet, which are short, fringed, and contained within the shell, are in constant motion, and, as above stated, answer the purpose of lungs. This motion, which is subservient to respiration, may readily be seen through the transparent shell. The heart, the contractions of which may be distinctly observed,

is an oval vesicle situate beneath the head. It is exceedingly abundant in many ponds and ditches, especially in horse ponds, seeking the surface in mornings and evenings, and in cloudy weather. It is often coloured, and then gives a brick-red or rusty colour to the water. It frequently moults, casting off its covering about every two days in summer. These *exuviæ*, or cast skins, form good objects. It is most plentiful from April to January. The shells of some species are beautifully reticulated, or marked with crossing lines so as to resemble net-work. The *Polyphemus* is another genus resembling the *Daphnia*, but distinguishable by the large size of its head, which is almost entirely occupied by a single enormous eye. It is not common in England, being chiefly found in a ditch near Richmond, nearly opposite Isleworth.

160. The third and fourth sections of the *Entomostraca* possess no branchial appendages to the feet. The species belonging to the third section (*Ostracoda*) possess little bivalve shells, so like to the shells of molluscs, that, but for the animals that inhabit them, they would doubtless be ranged with the oyster and mussel. They are chiefly collected under the genera *Cypris*, *Cythere*, &c. Some inhabit fresh and some salt water, the latter being found in the sand, or in the little pools left by the retiring tide. They are very minute, ranging from the $\frac{1}{10}$ to the $\frac{1}{200}$ of an inch. They may be readily recognised by the projection from the end and bottom of the shell of the fringed antennæ and feet. Two species of Cypris, *C. tristriata* and *C. vidua*, are common in ponds and ditches where the water is stagnant, but not putrid. The former is one of our largest species. The marine forms (*Cythere*, *Cythereis*) are to be met with in all the little pools among the rocks on the sea-shore, not swimming in the water, but walking among the fronds of sea-weeds or corallines, on which they delight to dwell. Some of the shells are beautifully dotted; and to them, in part, it is believed, the luminosity of the ocean by night is due. In former stages of this earth's history they must have swarmed to a prodigious extent, inasmuch as we find whole strata of great extent and thickness, which are literally crammed with the fossil shells of *Cyprides;* and in the chalk, shells of the marine species are found in great numbers.

161. In the fourth and last section of the order (*Copepoda*), the animals included in which are covered with a buckler,

we find the *Cyclops* (Fig. 30), an exceedingly common and interesting animal, abundantly inhabiting stagnant fresh water almost everywhere. The common species (*Cyclops quadricornis*) is most abundant in July and August, though it may be found all the year round. Its eggs are contained in two ovaries or bags, which hang externally from either side of the lower extremity of the body, and give it a very marked and peculiar appearance. The *Cyclops* is generally colourless, but in small pools of water on a loamy soil they are often of a rich, blood-red colour. It has been calculated by Jurine, who attentively observed their habits, that from one female 4,442,000,000 of young could be produced in a year. Another similar animal (*Canthocamptus minutus*), known by the name of the "Satyr," much more minute and elongated in form, is common in fresh-water ponds all the year round. Another (*Diaptomus castor*) has a narrow body in proportion to its length, a short bifid tail, and very long antennæ of great strength. The eye is large, of a fine ruby colour, and the muscles which move it may be clearly distinguished. It is common near London, &c., in spring and autumn. Many species of the same tribe exist in salt water, and are often to be found in the pools on the shore, among sea-weeds and corallines. One (*Cetochilus septentrionalis*) is found in enormous quantities among masses of jelly-fish, &c., floating on the surface in the Firth of Forth in the summer months.

A singular family belonging to the *Crustacea*, and very unlike the rest in appearance, is the order *Siphonostoma*, one species of which, *Argulus foliaceus*, called fish-louse, is an elegant object. It is about $\frac{1}{10}$ of an inch long, and is most commonly found attached to the stickleback, but is also found on the carp, roach, trout, pike, perch, tadpole, &c. It generally adheres to the gills, or immediately outside, or sometimes the under part of the pectoral fins.

162. The succeeding class, *Myriapoda*, will be dismissed in a few words. It contains those animals commonly known as centipedes, or hundred legs, and their allies, and is the lowest in which jointed legs are met with. The centipedes, of which there are many species, are good objects for low powers; and the respiratory system, which bears a strong analogy to that of insects, is also well worthy of examination. We are not aware, however, that the attention of microscopists has been specially directed to the animals composing this class, and it is probable that persevering investigation would reward the

observer with many interesting objects. The antennæ, legs, and spiracles will probably best repay attention.

163. *Cirrhopoda.* These are the animals known as barnacles, &c., and which are frequently found attached to logs of wood, which either are or have been immersed in the sea, bottoms of ships, &c., &c. They have soft bodies, which possess numerous long jointed arms which are fringed with cilia (sect. 172), a pair arising from each segment of the body. These are usually of a leaden or purple colour, and afford interesting objects. The animal is inclosed in a shell of several valves. Three or four species of *Lepas* (reputed as being the origin of the *Barnacle geese*) are common in our seas, attached by fleshy stems to ships' bottoms, floating wood, &c., and from any of these the ciliated arms may be obtained. The genus *Balanus* is sessile, adhering to stones, shells, wood, &c., and is popularly known as the acorn shell. It is of a conical form. Some of the species are very common on the coast. A transverse section of one of its shelly valves exhibits a cancellated structure like that of bone, which is very curious. An allied genus, *Coronula*, found attached to the backs of whales and turtles, exhibits the same structure.

164. *Annelida.* This class consists of worm-like animals, with a body composed of numerous segments, and circulating red blood. They usually have soft bodies, some of which present objects well worthy of attentive examination. In the first tribe (*Tubicola*) the branchiæ or gills form a most elegant tuft of branched filaments, disposed round the head. Their colours are most splendid, and few sights, when the animal is living, are more beautiful. Several species are common on our coasts. The *Serpulæ* inhabit twisted shelly tubes, which are usually attached to other shells or stones. The *Spirorbis* is a minute snail-like shell of a beautiful white colour, which may be found on all parts of the coast on sea-weeds, &c., and its animal, when living, is a most elegant microscopic object. The *Terebella* and *Sabella* inhabit a straight tube open at both ends, made of grains of sand, &c., agglutinated together, and the rejected tubes are found in multitudes on our flat sandy shores. All these may easily be obtained by dwellers or visitors at the sea-side, and exhibit the coloured gills in great beauty, and (especially the minuter species) will well reward the microscopic student for some pains taken in their investigation. The numerous feet are also worth examining; but they should by all means be studied while living.

165. The second tribe of this order (*Dorsibranchiata* its gills situate on the back, where they form beautiful crimson tufts, varying greatly in number and size. On side of each segment of the body are other appendage servient to locomotion, and which have been termed Both the gills and oars are worthy of minute examin Many species of this tribe are plentiful on our coasts. *Arenicola* or lob-worm is very common on sandy sho which it burrows, and may be found by the little he excreta left by it on the surface. Various species of may be found in hollows on rocks by the sea-shore, in c in sponge, among the roots of sea-weeds, in shells, &c some burrow in the sand. They are often called Sea-centi and the name certainly gives a fair idea of their appea They are carnivorous, and are furnished with a mouth o curious and peculiar structure. The ordinary mouth op appears very simple, and quite destitute of teeth, but it possesses an apparatus of most formidable character, can, when required, be made external, just as the finge glove, the tip of which has been inverted and pushed again made to resume its proper form; and then is disp "as pretty an assortment of rasps, files, knives, saws, or crooked fangs, wherewith to cut, tear, bruise, or hold prey, as any one could wish to see." The *Aphrodite*, c mouse, is a very beautiful animal of this tribe; and its l setæ or bristles exhibit a beautiful structure, which adm fits them for defensive weapons, being barbed on each s their tips.

The third and last tribe of the *Annelida* is the *Abranc* which have no gills. An interesting animal belonging t tribe is described and figured by Mr. Pritchard, unde name of the *Lurco* or glutton, and is a species of *Nais*. frequently found in fresh water, and is exceedingly vora and an interesting study, while living, for the microscope. medicinal leech also belongs here, and its teeth or horny are interesting objects.

166. *Entozoa.* This class comprises a vast number o mals, whose habitation is the interior of the bodies of ot some of the best known are those commonly called inte worms. Although the *locale* of these animals may inspire disgust at first, yet there are a large number of singular b among them, which are well deserving of microscopic exa tion, and there are probably few, comparatively, which

not afford interesting objects to the microscopist, though they appear, as yet, to have been greatly neglected in this respect. The mouth and neck are the most generally interesting portions, being usually armed with hooks, which may be in a double row, or covering the neck or body to a greater extent. But we will specify a few examples.

The *Cysticercus* is met with in many quadrupeds, especially pigs and ruminants, growing among the fat and intermuscular cellular tissue (the silvery tissues), and sometimes multiplying in such situations to a prodigious extent. Its shape is that of a flask, and its body is a simple bag filled with a clear fluid; but its head is a formidable weapon, armed with two circles of recurved hooks, by which it can anchor itself firmly to a given spot; below there are four oval suckers, by means of which it sucks, grows, and multiplies, till the animal it preys on falls sick and dies.

167. The *Cœnurus cerebralis* is found in the brains of the sheep and other ruminating animals. It is globular in shape, and sometimes grows to the size of a small orange, till its enlarged size causes dangerous pressure on the brain. The animal indicates its presence by dulness and listlessness, refusing to eat, and staggering in its walk, till death terminates its sufferings. The globular surface of this singular parasite is covered with numbers of heads and necks similar to the single one of the last-named, and the interior is filled with fluid.

The tape-worm is a well-known intestinal worm, composed of great numbers of joints. The neck is very much narrower than the rest of the body, and is terminated by a head of very similar structure to the preceding.

We might enumerate many similar species, but the above must suffice. The common "Hydatids," as they are termed, exhibit this structure, and some kinds of intestinal worms.

168. We now pass to an entozoon of different character, the *Echinorhyncus*.

These parasites, of which there are very numerous species, possess a mouth composed of a proboscis armed all over with strong hooks or spines, but which can, when required, be entirely retracted within the neck, like the mouth of the *Nereis* above described; so that they then appear the most innocent and harmless creatures. The use of the proboscis is to anchor themselves firmly in the viscera from whence they derive their food, and sometimes they even do more than this, and penetrate the membranes. In other species more formidable still, the whole body is studded over with sharp horny hooks, which fix like grappling-irons in the flesh. The *Echinorhynci* are usually found in the intestines of fish, birds, and quadrupeds, but most frequently in the first. Their appearance is commonly that of white, starved grains of oats. Thus *Echinorhyncus adfinis* inhabits the perch; *E. inæqualis*, the buzzard; *E. strumosus*, the seal; *E. fusiformis*, the salmon and trout; *E. haeruca*, frogs, &c., &c. The *Gyrodactylus* is found attached to the gills of certain fish, especially of the bream. Though only $\frac{1}{100}$ of an inch in length, the whole circumference of its adhering disks is armed with curved fangs as sharp as tiger's claws. It possesses also other larger hooks by which to fix itself still more securely to its victim, whose juices it feasts upon. On the gills of the same fish is found a very remarkable parasite (*Diplozoon paradoxicum*) of much larger size, apparently consisting of two long and two short arms; the two shorter being armed with broad suckers, and the two longer each with a mouth adapted to perforate the skin, and abstract blood. But very various is the structure of these parasites, especially among the lower animals, some having their heads divided into lobes, on which are placed sharp prongs—real tridents; such are met with in the perch and pike. Others have branching horns on their heads all covered over with hooks; these too are found in fishes. The perch also supports a very curious parasite, which lives embedded in the slime which covers the palate or tongue.*

169. But we must not quit the *Entozoa* just yet. The *Hydatid cysts*, which appear only like bladders, containing a fluid, and which are sometimes found in various parts of the human body, and oftener in other animals, especially in the liver of the sheep, and scarce resemble an animal and living structure, appear to be themselves infested with parasites; for if one be very carefully punctured, and its fluid very slowly drained off without moving the cyst, the interior will often be found to contain, either adhering to its side, or subsided in it, numerous granular bodies, like grains of sand. Examined under a tolerably high power they will be seen to consist of numerous globular bodies, connected with a central pedicle by short necks. In the fluid that escapes too many curious forms may be found. The bulbs of the hair in the human head are commonly occupied by three or four individuals of a micro-

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* For most of the details of the above three sections we are indebted to Professor *Rymer Jones's Natural History of Animals*.

scopic species, and the sebaceous or fatty follicles of the forehead, nose, &c., give occupancy to another and curious form. To obtain them, squeeze the neighbourhood of the little black spot or pustule, so as to force out the oily matter. This should be laid on a slide, and a little oil added to separate the animals. Cover them with a piece of thin glass and mount them.

A few animals are referred to this class which do not inhabit the bodies of any animal. Such are the "eels" of vinegar (stale), and those (*Anguillula glutinis*) found in paste which has been long kept. These are old and favourite living objects for the microscope. Very similar in form to these "eels" is a minute and curious animal (*Anguillula tritici*), found in grains of wheat. Occasionally grains of wheat, when ripe, are found to be of a dark green or black colour, constituting the disease called ear-cockle, purples, or pepper-corn. The last name gives a good idea of its appearance. The grain, when cut open, is found to be white and cottony inside. If a little of this cottony substance be taken up with a pin and laid in a small drop of water on a glass slide, it will be found, after a short time, on submitting it to the microscope, to be a dense mass of minute, living, eel-like animals, which often move and twist about with great activity. Sometimes it will be necessary to immerse the grains for some time in water before cutting them open in order to see the *Anguillulas* in motion.

170. We now come to the *Mollusca*, the bodies of which possess neither skeleton nor articulations, external or internal. The highest order of this sub-kingdom, the *Cephalopoda*, comprises those animals usually known as the nautilus and cuttle-fish. The nautili are the inhabitants of chambered shells; the cuttle-fish are without shells, but under the folds of the mantle is found a light calcareous substance, which is commonly known by the name of cuttle-fish bone, and which affords an interesting microscopic object. A thin vertical section of it exhibits a wonderful contrivance "for the purpose of obtaining the greatest amount of solidity with the least possible weight. The carbonate of lime and animal matter of which this substance is formed, are deposited by the animal in plates, separated by thin vertical columns, arranged in a zigzag manner. To view the arrangement of the vertical columns to advantage, it must be observed as an opaque object, and is prepared by taking off one of the plates without disturbing the columns, which, by a little dexterity,

may be left attached to a lower plate. The cuttle-fish bone, therefore, supplies two sections, one cut at right angles to the other."

171. The chief remaining members of the sub-kingdom Mollusca, are those which are furnished with a shell, comprising the *Gasteropoda* (univalves), and *Lamellibranchiata* (bivalves), with a few other tribes of little importance here. The animals of the *Gasteropoda* or univalves commonly possess a gizzard, or muscular stomach, for the purpose of more perfectly grinding or masticating the food, which is taken by the mouth. In many species this organ is provided with cartilaginous, or even calcareous projections or teeth, fitted to divide the food. When this gizzard is completely extended and expanded, it forms a very beautiful object, or rather class of objects, for it differs greatly in form in different species. It must be obtained by carefully dissecting it from its attachments within the head. The following animals afford beautiful examples :—

Zonites cellarius.
Patella vulgata ; limpet.
Buccinum undatum ; whelk.
Lymnæa stagnalis.
Doris tuberculata.
Haliotis tuberculata.
Trochus zizyphinus.
Planorbis corneus.
Helix aspersa.
—— hortensis.
Periwinkle.

172. In many of the animals belonging to the division *Lamellibranchiata* (or bivalves), the beautiful and remarkable phenomenon of *ciliary motion* may be well seen. The term, perhaps, requires a brief explanation. Cilia are minute filaments, like eye-lashes, which are in a state of constant vibration, and this motion is often, perhaps mostly, involuntary on the part of the animal, as much so as the action of the heart in the higher orders. It is difficult to understand what causes the motion : it can scarcely be muscles in organs so excessively minute ; but it is thought by some that motion is inherent in the cilia, that they move by a power of their own, as long as life lasts. They are most readily observed in the lower animals, though they exist in the upper ranks of the animal kingdom, and even in man himself. All the air-tubes and air-cells of the lungs are lined by a mucous membrane, which is continued from the back of the mouth, and this membrane is covered with cilia which are in perpetual motion. If the mucous membrane of the palate of a frog be carefully scraped with a scalpel, and a minute quantity of what is re-

moved be placed upon a glass slide, and removed to the stage of the microscope, and examined with a pretty high power, the *Epithelium* cells, which cover the mucous membrane there, will be readily perceived, and the cilia which terminate them will be seen in constant motion. The probable use of the cilia in these places is to keep in motion the fluid which is continually being secreted from the surface of the mucous membranes, and which, if allowed to accumulate in the air-cells, would produce great inconvenience, if not suffocation. In the lower animals, however, cilia perform a great variety of important offices, especially in the currents they create in the water, bringing within reach of the mouth of the animal, the minute infusoria, &c., on which they feed. In the mollusca, fishes, and other aquatic animals, the gills are covered with cilia, by the incessant vibration of which the water in contact with the gills is kept in rapid motion and constant change ; by which means the blood, passing through the gills, is more speedily and effectually aërated than it otherwise would be. This motion of the cilia may be readily observed by cutting off a very minute portion from the edge of the branchiæ (usually called the " beard ") of the oyster or mussel, and placing it on a clean glass slide, with a drop of the liquor out of the shell (fresh water would cause its instant cessation). On being placed under a ½ or ¼ inch achromatic object-glass, the cilia fringing the lobes of the branchiæ will be seen in rapid and continuous motion, producing strong currents in the water. Cilia and ciliary motion will again come under our attention.

173. We must now state very briefly what is known of the structure of *shell*. This has been extensively investigated by Dr. Carpenter and Mr. Bowerbank, and they have classified shells, according to their internal structure, into five sections.

1. Those possessing prismatic cellular structure, as in thin sections of *Pinna*.
2. Those whose shells are membranous. Ex. *Mya. Anatina. Thracia.*
3. Shells with a pearly substance, as the interior surface of some species of *Ostrea* and *Mytilus*.
4. Tubular structure. Ex. outer layer of *Anomia Ephippium*, *Lima scabra*, *Chama florida*.
5. Cancellated structure in some fossil shells.

The following shells will afford interesting sections, and are all easy of attainment :—

Mya arenaria (section of the tooth).—A common sea-shell, in sand.
Pinna ingens.—Found in deep water in our southern, western, and northern coasts.
Arca Noæ.—Western coast of England.
Avicula margaritifera.—Mother-of-pearl shell.
Anomia ephippium.—Common on rocks on our coast.

CHAPTER VIII.

OBJECTS.—THE ANIMAL KINGDOM—RADIATA.

174. We now pass to the last great division, or sub-kingdom of the animal creation, viz., the *radiate animals*. The first of the five classes into which they are divided, the *Echinodermata*, furnishes us with a series of exceedingly beautiful objects in the spines with which the shells of some species are thickly set. Those we refer to are the various species of *Echinus*, *Cidaris*, &c., some of which are well known to most frequenters of the sea-coast by the names of sea-urchins, or sea-eggs, a very common species on our coast being the *Echinus esculentus*. The spines, with which the shells are thickly covered, are among the most beautiful of microscopic objects, when thin transverse sections are cut from them, and mounted in Canada balsam. The exquisite regularity of the arrangement of the minute cells of which they are composed makes them somewhat resemble a section of a twig; but the rich colours with which they are frequently invested, and the different arrangement and form of the cells, give them a still more elegant appearance.

175. Some special precautions, in cutting these sections, are necessary. The sections should first be cut in the rough with a very fine saw, and then filed down till about the thickness of card; the side filed is then to be rubbed smooth with water, on a water of Ayr stone, and then carefully dried, first on white blotting-paper, then by a gentle heat, till all moisture is perfectly expelled; then with some Canada balsam, hardened by age or heat, so as to be scarcely indented by the nail when cold, fasten it by heat to a slip of glass. Next pour on it some thin balsam, and gently heat it till every pore is saturated with the balsam, and all air is driven out. The gentle heat is then to be continued (so as not to allow

bubbles to form in the balsam), till the balsam will set, on getting quite cold, to about the same degree of hardness as that used to cement the section to the slide. This being well effected, the balsamed section is to be again cut down by file and hone till it is reduced to the requisite thinness, and being finally polished with putty powder and cleaned, a thin glass cover, smeared with balsam, may be put on with a very gentle heat, and the section is mounted. Practice alone, however, will make the operator perfect in this operation; success in which is difficult from the great brittleness of the texture of the spines.

The following are the British species of most frequent occurrence, whose spines are large enough to cut. Portions of the shell, cut in the same manner as directed for the spines, exhibit a similar structure :—

Echinus esculentus.	Common on rocks near low-water.
—— lividus.	Ireland, in the south, common, perforating the low ledges of rocks, which are never left quite dry from the Shannon to the Isles of Arran; also about Berehaven and Bantry. Sections of the spines of this species are very rich in colour.
—— miliaris......	Abundant in the Irish Sea, on the west coast of Scotland, south shores of England, on oyster beds and scallop banks, with the common species.
—— Flemingii.	Rare, deep water in Shetland, south-west of Ireland.
Cidaris papillata.	Shetland, in deep water, called "the piper."

The following foreign species afford exquisite sections of spines :—

Acrocladia (various species), beautifully rich in colour.

Echinometra heteropora, —— lucunter, Heliocidaris variolaris,	Pattern of the structure very beautiful.

176. Scattered among the spines of the *Echini* are a number of very minute bodies, called *Pedicellariæ*, concerning the nature of which there has been much discussion. They look very much like a single calyx of a campanula, with its wing flower-stalk, and with only three (instead of five) of the narrow calyx leaves, after the flower has dropped off and the seed is ripening. The *Pedicellariæ* are, however, exceedingly small. Animal they undoubtedly are; but whether they are part of the *Echini*, as some think, or whether they are small parasites, like encrinites, as others suppose, we are unable to state. The former is the opinion now most generally held. Some of them are very beautiful microscopic objects, and they well deserve attention and further investigation. The spines of *Ophiura rosula* (one of the brittle stars), and those of Spatangus

(Fig. 55) and *Clypeaster* (in which they are minute and bristle-like), are beautiful opaque objects. The calcareous corpuscles and the *Pedicellaria* of the common star-fish are also interesting. Closely allied to the *Echini* in structure, though very different in appearance, are the animals known as *Holothuriæ*, or sea-cucumbers. The microscopical examination, however, of their skin reveals points of resemblance in certain calcareous spines and plates which are scattered through its substance, and which may be isolated for mounting as directed for the spicula of *Alcyonia* (sect. 181). Those found in the skin of species of *Holothuria* and *Synapta*, and in *Chirodota violacea* (a Mediterranean species), are very interesting.

177. We now enter upon a class which has always held a high place in the esteem of microscopical observers, the *Polypifera.* The genus which is best known, and which has attracted universal attention, is the polype *par excellence* (*Hydra viridis*), which is common in fresh-water plants, in ditches, &c. Its extraordinary power of maintaining its vitality when cut to pieces, and the still more marvellous property, by virtue of which every one of those pieces grows to a perfect and distinct polype, is one of the most wonderful phenomena which the animal kingdom exhibits to us. They are commonly found in ponds, very slow brooks, and ditches, attached to aquatic plants, and resembling, when contracted, which they always are when at all disturbed, a small globule, not so large as a pepper-corn, of greenish or brownish jelly. If allowed to remain perfectly at rest, this globule lengthens itself till it forms a tube, and then extends from its fore extremity, several exceedingly fine *tentacula* or arms, which it moves freely about in all directions in search of food. Under a very low power the character, structure, and habits of the animal may be very conveniently studied, and will afford much pleasant occupation to the microscopist.

178. Scattered among the green and red sea-weeds of the shore, every sea-side visitor must have observed numerous tufts of "sea-weed" (so called), of a light brown or horn colour, looking more like fine brown hair than anything else (Fig. 39); and those who have gathered and dried the former, almost invariably collect the latter kind among the rest, and regard them as favourites, on account of their elegant forms, the ease with which they are dried, and the certainty of their retaining their natural colours. Sea-weeds, however, they are not, for *they are* rather corallines—the habitations of multitudes of

polypes, and belong to a family of the *Polypifera*, termed *Sertulariadæ*. If minutely examined with a lens of low power, or even with the naked eye, they will be seen to consist of a main stem, frequently branched, and clothed on either side with projections resembling the teeth of a saw. If a fragment be now placed under the microscope with an inch or ½-inch object-glass, these tooth-like processes will be seen to be cells of a triangular or flask-shape, and with the aperture on the upper side. At certain periods of the year larger cells of a different shape make their appearance here and there, much resembling the capsule of a moss in shape, and something also in function, inasmuch as in them are formed, and from them eventually are discharged, the germs which are to originate fresh individuals.

179. But to see the full beauty of these objects, the observer should obtain a piece or two in a living state, either detached from the rocks or shells on which they grow, or as collected by the dredge, and instantly they are removed from the water they should be transferred to a vessel of sea-water, till they can be examined. If one of these pieces be now placed in a watch glass, supplied with a little sea-water, and placed under the microscope, being allowed to remain perfectly at rest for a time, from out of every cell a flower-like polype will gradually emerge, and, waving their delicate arms about in the water, will present a spectacle of extreme beauty, on which the observer will long gaze untired. More extraordinary still, the horny stems on which the hundreds, and perhaps thousands of cells are placed, are not *mere* stems and branches, but hollow tubes, filled with a soft, living marrow or pith, with which the bodies of the whole host of polypes are continuous—so that it is but one animal, though many—either it is a host of animals with a common body, or it is a single body with a thousand hydra-like hungry heads. Mr. Gosse, speaking of this sight, says, "It seems to me a poor thing to strain one's eyes at a microscope over a dead and dry *polypidom*, as it does to examine a shrivelled and blackened flower out of an herbarium, though I know well both are often indispensable for the making out of technical characters. But if you want to get an insight into the structure and functions of these minute animals, or if you would be charmed with the perception of beauty, or delighted with new and singular adaptations of means to an end; or if you desire to see vitality under its most unusual, and yet most interesting

phases; or if you would have emotions of adoring wonder excited, and the tribute of praise elicited to that mighty Creator who made all things for His own glory, then take such a zoophyte as this, fresh from the clear tide pool, take him without inflicting injury; therefore detach with care a minute portion of the surface rock, and drop your prisoner, with every organ in full activity, into a narrow glass cell with parallel sides, filled with clear sea-water, and put the whole on the stage of your microscope, with a power of not more than 100 linear at least for the first examination. I greatly mistake if you will not confess that the intellectual treat thus obtained is well worth, ay ten times more than worth, all your trouble."

180. Dr. Golding Bird has pointed out a method of preserving permanently, to some extent, this beautiful exhibition for renewed examination at pleasure, at least so far as to exhibit the polypes *in situ*, with their tentacula expanded:—"For this purpose a lively specimen should be chosen, and then plunged into pure cold water; the *polypes* are killed almost immediately, and their tentacula do not retract; proper sized specimens should then be selected, and preserved in weak alcohol. Little phials, about two inches long, should be procured, made from thin flat glass tubes, so as to be ½ an inch wide, and ¼-inch, or even less, from back to front. The specimens should be fixed to a thin platinum wire, and then placed in one of these phials (previously filled with weak spirits), so as to reach half way down. When several are thus arranged they should be put in a glass cylinder, and removed to the air-pump. On pumping out the air, a copious ebullition of bubbles will take place, and many of the tentacula previously concealed will emerge from their cells. After being left in vacuo for a few hours, the bottles should be filled up, closely corked, and tied over like anatomical preparations in general. For all examinations with a one or two inch object-glass, these bottles are most excellent, and afford cheap and useful substitutes for the more expensive and difficultly managed cells. A few dozen of these bottles hardly occupy any room, and would form a useful accompaniment to the microscopist at the seaside." The *polypidoms*, or coralline-like clusters of cells, afford nice objects for low powers, and may be mounted either dry or in Canada balsam. The caverns at Tenby may be mentioned as a specially rich locality for sponges and zoophytes. We append a list of the most interesting and easily obtained

species, and for further information must refer the inquirer to Dr. Johnston's *History of British Zoophytes*, in which full details will be found.

Thoa muricata.
Sertularia rugosa.
—— rosacea.
—— pumila.
—— tamarisca.
—— operculata (Fig. 89).
—— argentea.
—— cupressina.
Thuiaria thuja.
Plumularia falcata.
—— pennatula.
—— cristata.
Laomedia geniculata.
—— gelatinosa.

181. The next order of the *Polypifera*, which possesses interest for us, is the order *Asteroida*, which includes the *Alcyonian polypes*. A very common production of this kind is constantly to be observed on our shores. It looks like half-jelly, half-sponge—too firm for the former, too gelatinous for the latter. One of the species is very common upon stones and shells in deep water, covering them with a gelatinous crust, from which rise lobes of various sizes and lengths, and by fishermen it is commonly termed dead men's fingers. Dried, they closely resemble sponges. These productions are the habitations of very numerous polypes, and contain scattered through their substance numerous *spicula* or minute, sharp-pointed, crystalline substances, which form the chief attraction to the microscopist in the animals of this tribe. They may be either calcareous (composed of lime), or silicious (of flint). In the common *Alcyonium digitatum* (dead men's fingers) of our seas, they are usually in the form of a cross, and toothed at the sides, and when carefully freed from the flesh in which they are enveloped, form beautiful microscopic objects. To obtain them boil thin slices of alcyonia in solution of caustic potash, and afterwards carefully wash the sediment, taking care to allow it thoroughly to subside before pouring off the water. After repeated washing, the sediment will be found to consist entirely of spicules of the *Alcyonium*.

182. The *Gorgoniæ* belong to this tribe, and though by many called corals, yet they differ from them in their more horny texture. Some idea of them may be gained from a species which is very frequent as an ornament in our houses —the sea-fan or Venus's fan (*Gorgonia flabellum*), which somewhat resembles a flat horny net, arising from a stony base. Species of *Gorgonia* are found in every sea, chiefly in deep water, and possess, when recent, a hard central skeleton, which is covered with a soft outer coat in which the spicula

are chiefly contained. The following are the British species, concerning which ample details are given in Johnston's *British Zoophytes.*

Gorgonia verrucosa.
—— placomus.
—— anceps (Spicula, Fig. 53).
Gorgonia lepadifera.
—— umbraculum.
—— nobilis.

In most of the species of *Alcyonium* and *Gorgonia*, the spicula are calcareous, and are often, especially in some foreign species, of beautiful forms and richly coloured. One of the most remarkable species of alcyonium (*A. poculum*), is a native of the coral reefs of Sumatra, and has silicious spicula, which may be obtained in the manner that will be directed for sponges. In some sea-sand from Java, full one-third the bulk was composed of spicula of different species of gorgonia, alcyonium, and sponges, and one-third of the remainder of foraminiferous shells. They may be mounted in Canada balsam, but the heat must be very cautiously applied, as it speedily destroys the tints of the red and other coloured species. Other interesting species of this family are

Pennatula rubra.
Renilla Americana.
Isis hippuris.
Gorgonia muricata.
—— petechialis.
Muricæa elongata.

183. We now pass to the next order of the *Polypifera*, the *Cilio-brachiata*, the polypes of which have the tentacula or arms covered with cilia. They are called *Bryozoa* (moss-like animals) by some naturalists. This order also possesses great interest for the microscopical observer. A very abundant production on our shores, belonging to this tribe, is the *Flustra*, or sea-mat, which every sea-side visitor must have seen, showing its lobed, sand-coloured, leaf-like masses among the green and red sea-weed which every tide throws up. Many call it a sea-weed too, but it may be distinguished most readily by its colour, its harsh and firm feel, and by the dulness of its surface, which requires only the application of a common magnifying glass to perceive that it is entirely composed of open cells; indeed, they may be seen by a good eye, even without such aid. These cells are inhabited by elegant polypes when living, which are of as exquisite beauty as those described in sect. 179. Some species of *Flustra* are found incrusting shells, stones, and sea-weeds, and resembling a covering of white gauze over their darker support. Some of these may be found everywhere on the shore. All the *Flustræ* must be *mounted* as opaque objects, and some are very beautiful. A

few species belonging to the order have, however, a great resemblance to the *Sertulariadæ*, and like them, should be put up as transparent objects. There are several other forms of coral or coralline, contained in the order, many of which are worthy of attentive examination and study, and are excellent opaque objects. The following list will embrace some of the most interesting and attainable British species:—

Flustra foliacea
—— truncata } leafy species.
—— carbasea
—— membranacea } incrusting.
—— carnosa
Cellepora ciliata.
—— avicularia.
Farcimia salicornia.
Retepora reticulata.
—— cellulosa.
Eschara foliacea.

Lepralia nitida
—— coccinea
—— variolosa
—— ciliata (Fig. 49) } incrusting species.
—— trispinosa
—— immersa
Cellepora pumicosa
Membranipora pilosa
Valkeria pustulosa
Hippothoa catenularia } resembling Sertularias.
Notamia loriculata
Serialaria lendigera.

There are thirty-seven species of *Lepralia*, native in our seas, all of which are interesting; the above are the most accessible. *Cellepora avicularia* (the bird's-head coralline of Ellis) is a rather rare but highly curious coralline. In the coralline crag of Suffolk, as found at Aldborough, Sutton, Ramsholt, &c., species resembling many of the above may be found fossil in profusion, in small fragments, it is true, but amply sufficient for the microscope; and there will be no difficulty, with a little patience, in selecting many interesting specimens for this purpose in any of the above localities.

184. Somewhat different in outward appearance, though belonging to the same group, are a few species which demand our notice ere we pass on to the next tribe. One of these is the *Bowerbankia*, a small, thread-shaped, creeping, parasitical, conferva-like polypidom, often found clustering thickly upon *Flustra foliacea*. It is as a living object that this will chiefly interest the microscopical observer. The *Polypes* which inhabit its thick-clustered cells are, when fully expanded, about $\frac{1}{12}$ of an inch in length, but even when retracted, so transparent are the horny cells, that they may be distinctly observed, and their structure seen. Its organization is much more complicated than that of the common polype (*Hydra*) mentioned above, for it possesses an œsophagus, a gullet, a gizzard, a stomach, and an intestine, while numerous little bags or follicles scattered over the surface of the stomach appear to secrete bile, and to perform the functions of a liver. These

various organs, and the mastication and digestion of the food, and the subsequent rejection of the fæcal remains, may all be observed in the living animal under the microscope, as the transparency both of the animal and its cell afford unusual facilities to the observer. *Bowerbankia densa* and *B. repens*, are both British species, and are not rare. Some fresh-water kinds (*Alcyonella* and *Plumatella*) are not uncommon in lakes, streams, and ditches. In the *Rotifera* we shall meet with some small animals of very similar construction.

185. From the *Polypifera* we pass to the sponges, which will require a brief notice. The fibrous, elastic tissue, of which the common species are composed, is familiar to every one, and is exhibited under a great variety of forms. Interspersed throughout this substance are very commonly scattered multitudes of minute spicula, analogous to those described as obtainable from *Alcyonia* and *Gorgonia*, with this exception, that while the spicules of the latter are calcareous, those of the sponges are usually silicious. Sponges are met with in most seas, growing in abundance on the rocks. The ordinary sponge, which is used for domestic purposes, does not, we believe, contain any spicula; but there are a vast number of other species, some 25 or 30 being found in our own seas. The majority of these contain the spicula, some of which resemble doubly-pointed needles; others with heads like pins; others like a caltrops or ball of spines; others in the form of grappling irons, &c. &c. Some foreign species are so full of spicula as to be very harsh and firm to the touch. With these the sponge also contains *gemmules*. These are the germs or eggs of the sponge, which are frequently covered by a network of spicula, or have their substance thickly penetrated by them. The remainder of the gemmule is gelatinous, like the living portion of the sponge. The silicious gemmules are, like the spicules, very interesting and beautiful objects. To isolate them from the sponge, it may, when they are silicious, be digested in strong nitric acid till the animal and horny parts are entirely dissolved, and then repeated and careful washings will render them clean and fit for mounting. We ought, however, to remind the operator of the cautions we have given with regard to similar processes in sections 181, 201, and 206. The following British species of *Grantia* possess triradiate and club-shaped *calcareous* spicules. These sponges are whitish, firm, and nearly without elasticity. They may be treated as the alcyonia. *Grantia compressa*, *G. botryoides*, *G. nivea*,

G. coriacea, *G. ciliata.* They are frequent on rocks and seaweeds near low-water mark. The British species of *Halichondria* all possess simple *silicious* spicules; some of them are very common. *Tethya lyncurium*, which is almost like a ball, is found on the coast of Devon and the bays of Connemara, and contains both simple and stellate silicious spicules. Those of many foreign species are, however, the most beautiful.

186. Belonging to the same general division of the animal kingdom, and closely allied in structure, though widely different in external form, is a very remarkable group of minute animals, which form very elegant calcareous shells, termed from the numerous pores with which they are studded, *Foraminifera* (Fig. 38). Being divided by septa into numerous chambers, they were at one time classed with the *Cephalopods* from the similarity between their shells and the multilocular shells of the nautilus and ammonite; then they were considered as being formed by polypes; but their character and rank is now decisively settled, many species having been examined and observed in a living state. The animals which form them are gelatinous in substance, and are furnished with numerous long filaments of the same nature, like fibrous roots, stretching out in every direction. With these they seize their food and convey it to their mouth. They are termed *Rhizopods* or root-footed animals.

187. We have said that the shells of the *Foraminifera* are divided into numerous chambers by partitions or septa; these are pierced full of the finest pores, by which means a communication is maintained between the various divisions of the shell. Many species are to be found on almost every coast; but those which are natives of this country are very minute. They are, however, in the highest degree worthy of examination; and a careful search on our sandy shores will probably soon furnish many species. Messrs. Legg and Woodward found the sand on the north side of Portland Bay to be marked with white ridges, many yards in length, and parallel with the edge of the water. These proved to consist of myriads of *Foraminifera.* The surface of the mud of Shoreham harbour also afforded a harvest of these minute shells; and the ooze from oyster beds is known to yield many species. The surface of ooze and sandy shores sheltered from the direct action of the sea, may probably be examined with advantage for them. The Kentish shore at Sandwich, Sheppey, Sea-

salter, &c., will probably be found fruitful localities. The sand of the shores of the Adriatic sea contains numerous *Foraminifera,* large enough to be recognised by the unaided eye.

188. A very abundant source of foreign specimens of *Foraminifera,* and one more easily accessible to most microscopists than any of the above, is the sand which is constantly shaken out of sponges, especially those imported from the West Indies. A greater or less quantity may usually be obtained from any one who sells sponges, for the asking. This sand is always more or less rich in these beautiful organisms, and with a little patience numerous specimens may be found with the aid of a common lens, or the simple microscope, and a small camel's-hair brush, wetted and drawn through the lips to a point to pick them out with. Mr. Legg recommends a more rapid method. He sifts the sand through wire gauze of 10, 20, 40, 70 and 100 wires to the inch successively. The first sifting clears the sand of clippings of sponge, pebbles, &c. The second, third, and fourth pieces of gauze separated a large quantity of various species of *Foraminifera,* almost pure from sand or other admixtures. By gently agitating the remaining sand in a dish with water, a variety of the very minute species may be collected together on the surface of the sand, whence they may be easily transferred by a camel's-hair pencil. Another simple method for separating them from the sand among which they are found, is by exposing it to a *moderate* heat for many hours in an oven, so as absolutely to expel every particle of moisture. When cold it is to be lightly sprinkled on the surface of a basin of water; the grains of sand will sink, but the shells (having their chambers filled with air) will float and may be skimmed off. The variety observable in these beautiful shells may be inferred from the fact, that D'Orbigny describes 575 species as peculiar to the torrid zone, and 350 to the temperate zone; and great numbers in all probability remain unknown and undescribed.

189. The *Foraminifera* abounded no less in the earlier periods of the world's history than they do now; in fact, some of the rocks show that they teemed to an incalculable extent, especially during the later secondary and the tertiary periods. Chalk abounds with them, and to such an extent, that it is asserted that in the chalk of the south of Europe they constitute nearly the whole mass. In the chalk of our own country they are less abundant, but in many localities, as in Norfolk, *at Gravesend,* and at Salisbury Plain, they may be found in

considerable abundance (Fig. 48). In many specimens of chalk their numbers exceed a million in each cubic inch. A minute quantity of the chalk scraped into a little Canada balsam on a glass slide, and then heated for some time, will show them, if present. The following method has been suggested for reducing the chalk to an impalpable powder, so as to enable the *Foraminifera* (or *Polythalamia*, as they are sometimes called) to be separated by repeated careful washings. Boil a lump of chalk in a saturated solution of sulphate of soda; when thoroughly penetrated by the solution, set it aside to crystallize. The act of crystallization tears asunder every particle of the chalk without breaking the shells. Finally, dissolve out the sulphate of soda with warm water, and by repeated careful affusions of water remove the fine particles of chalk so as to leave the shells. In some of the tertiary strata they occur in immense quantities. One of the tertiary limestones which abounds near Paris, and is there termed *Calcaire grossier*, is full of shells, and several thick beds of it are entirely composed of a very minute foraminiferous shell, the *Miliola*, so called from its resemblance to a grain of millet seed. A cubic inch of this stone from the quarries at Gentilly contains on an average 58,000 shells. The *Nummulite*, another genus of foraminiferous shells, is found in incredible numbers in many strata, in some places forming the bulk of the rock of which whole mountains are composed.

190. Here also, probably, are to be placed a group of animals with silicious shells, in many respects resembling the *Diatomaceæ* (sects. 199-206), but of very different form. As far as can be ascertained from the few that have been detected in a living state, they appear to have similar filamentous prolongations, and to be inhabited, or rather secreted by animals of the *Rhizopod* type. They are termed *Polycystina*, and are very various in shape, many being globose, others flask-shaped, others cup-shaped, &c., very commonly furnished with spines, and nearly always drilled with very numerous perforations, through which the filaments pass (Figs. 63 to 68). Though usually so small as to be invisible to the unaided eye, they are replete with beauty. An immense collection of the shells of these animals is found in a bed of friable rock resembling chalk, at Springfield, Barbadoes. They are imbedded in a calcareous paste, which, if dissolved away by a proper acid, leaves these exquisitely elegant structures free from extraneous matter in all their rich beauty and in the greatest profusion. Upwards

of 300 species have been discovered and described from that locality alone. They probably abound in the mud of the ocean, though, from their minute size, they have long escaped notice. They have been detected by Ehrenberg at Cuxhaven, and were found with *Diatomaceæ* and *Foraminifera* in the soundings of the Atlantic.

191. We now come to the last class of the animal kingdom, the *Polygastrica*, or *Infusoria*, which have been one of the most favourite subjects of research ever since the microscope revealed them to us. Nor is this at all surprising; for so universally are they present, so strange and varied are their forms, so curious their habits, so important their functions, so vast and inconceivable their numbers, so unparalleled their rapidity of reproduction, and so minute in their size (being ordinarily invisible to the naked eye), that they present a subject of study of the highest interest and attraction. "They are a mighty family, for they frequently, in countless myriads, cover leagues of the ocean, and give to it a strong tinge of colour from their vivid hue. They are discovered in all climes, have been found alive sixty feet below the surface of the earth, and in the mud brought up from a depth of 1600 feet in the ocean." Upwards of 2440 species are known and described. We have reserved it to this place to give a general account of the animals termed *Infusoria* or *Animalcules*, though some (the *Rotifera*, or *wheel animalcules*) are now considered to hold a higher rank in the scale of animal existence, and are associated with the *Articulata;* and another group (the *Diatomaceæ*, sects. 199-206), to which we have already referred, are so nearly allied to the vegetable kingdom, that by very many observers they are considered as plants, and it is very probable that such will be eventually proved to be their true place. As, however, both these tribes are called animalcules by ordinary observers, and have, until recently, been so considered by naturalists, we have reserved for this place all details concerning them.

192. We commence our survey of these interesting organisms, with the highest and most complex in structure among them, viz., the *Rotifera*, or wheel animalcules. These are, however, very minute, ranging in size from the $\frac{1}{800}$ of an inch, to the $\frac{1}{16}$ in the largest. They are very transparent, so that their internal structure and functions can be readily observed, and are usually elongated in form. The head ordinarily occupies one extremity, and frequently bears one or two red spots, *which are* by some regarded as eyes. At or near its termina-

tion, are one, two, or more circles of cilia, which, in some species at least, move in such a manner as to produce the appearance of minute wheels revolving rapidly on their axis; whence they obtain their appellation. The body is included in a double sheath, of which the outer is somewhat loose, being sometimes bag-like, and sometimes a horny, or even flinty cell, into which the animal can retract itself at pleasure. They possess an œsophagus, or gullet; a gizzard, provided with four teeth, which are fixed on hard jaws, moved by powerful muscles; a stomach, into which the food enters, after being masticated by the gizzard; and an intestine. The object of the rapid motion of the cilia is to create such currents and whirlpools in the water as shall bring within reach of their mouth the animalcules, &c., on which they feed. This ciliary motion is entirely voluntary, for it is only put into play when the animal desires food, and ceases when it is satisfied. The extraordinary character and habits of the wheel animalcule excited the most intense interest among microscopical observers when it was first discovered by Lewenhoeck, nor is it less astonishing to those who view it for the first time. The rapid (apparent) revolution of the circles of cilia is as singular as if a man's head were to commence rapidly revolving on his shoulders; and yet so perfect is the optical illusion, that few who have seen it can believe that the wheels (so called) are *not* revolving. Still, it *is* apparent only, and is caused by the cilia being first depressed, then elevated again, and this not at the same moment all along the circle, but each in rapid succession, which gives to the observer the impression, that the ring is revolving. Another most remarkable circumstance about the *Rotifera* is their vitality. Though aquatic animals, they may be dried up, carried from place to place by the winds, lie, it may be for months, as dust, and yet revive, on the application of water, to life and vigour again. This seems so startling, that many will not believe it; and yet it has been authenticated by the experiments of very numerous and distinguished naturalists, and may be tested by every one. Some of the *Rotifera* produce their young alive, others lay eggs; and it is stated that these eggs possess this strong vitality to a much greater degree than even the full-grown animalcules.

193. The *Floscularia* are a very interesting family of the *Rotifera*, which have excited some attention of late, chiefly from the account given of them by Dr. Mantell. One of these is the *Stephanoceros Ehrenbergi*, or crowned animalcule. It

possesses five tentacula, or arms, which are covered with cilia, in circular tufts, reminding one of the *Cilio-brachiate polypes*, previously described (sect. 183), which in many respects it greatly resembles. The animal is contained in a transparent tubular cell, and is very sensitive, and contracts within its case on the slightest alarm. It is, when contracted, about $\frac{1}{24}$ of an inch long, and, when extended, about $\frac{1}{10}$. It is usually found on the stems and under side of the leaves of the water-lily, and other aquatic plants. The *Melicerta* is a very beautiful animal of the same family; its cylindrical case or cell being entirely covered, when full-grown, with circles of beads, which are pellets deposited by the animal, so that it is "a mason who not only builds up his mansion brick by brick, but makes his bricks as he goes on, from substances which he collects around him, shaping them in a mould, which he carries on his body." Mr. Gosse (in the *Transactions of the Microscopical Society*) gives a very interesting account of this animal and its habits. It is found on the roots of duckweed, and other floating plants, and is somewhat smaller than the *Stephanoceros*. Another polype of similar character, but not beaded, may frequently be found attached to the stems of the hornwort (*Ceratophyllum*), which is not uncommon in shallow stagnant waters and slow streams.

194. We have not space, nor is it necessary to enter into detailed descriptions of other species of *Rotifera*; a few directions for obtaining them will be serviceable. It is useless to search for them in vegetable infusions which are becoming putrid, though they swarm with countless myriads of other kinds, and are commonly looked to to furnish specimens of *Infusoria*. They may be found in gutters and troughs, in the red sediment left after the rain water has evaporated. The leaden troughs appropriated for birds to drink out of commonly contain them. They may also be obtained by steeping a small bunch of hay in water, and many species are found in abundance on water plants, such as duckmeat, &c. The edges of ponds may also be searched for them, and, indeed, in these two latter situations, a large proportion of the most interesting animalcules may be found. When they are found in small pools, where these have been reduced by evaporation, they are often of a beautiful red colour, and are sometimes so abundant, that thirty have been counted in a single drop. They are found very abundantly about farm-yards, in collections of stagnant water covered with weeds and confervæ, and

are in greatest perfection during June, July, and August. They are fond of sunshine, and are seldom to be taken in cloudy weather, as they then sink to the bottom. They may be preserved for a great length of time in a glass vessel, in rain water, taking care that no decomposing vegetable matter is allowed to accumulate, and adding from time to time a stem or two of new hay, having previously removed the old. The water fleas (*Daphnia*), and the cyclops (sections 159, 161), devour them greedily, and must therefore be carefully excluded from the water in which they are kept.

195. We now pass to the *Polygastrica* proper. These are the animalcules, usually and properly so called. They are called *Polygastrica* (*polys*, many, and *gaster*, a stomach), because they are said to possess a large number (sometimes as many as 200) of stomachs, or digestive sacs, which hang, in some species, on every side the œsophagus, or cavity into which the food is received, like currants on a bunch. This is the character assigned to these minute beings by Professor Ehrenberg, who first gave them the name *Polygastrica;* he has made them the special objects of his study during many years, and perhaps knows more of them than any other living naturalist. His opinions have, however, been controverted by many eminent men, who doubt whether the small cells observable in the bodies of the animalcules, are stomachs at all; but we cannot here enter into the question. They abound everywhere. The lake, the pond, the stagnant ditch, the sea, swarm with them, and they are even found in the earth itself. The earlier microscopic observers found them chiefly in decaying infusions of vegetable matter, and hence they were called *infusoria;* and for *some* species, these are still the most abundant sources. Let any vegetable substance, such as a few leaves, or a sprig of hay, be steeped in water for a few days, and the film on the surface, or at the edges of the vessel, will be found to contain myriads, sporting in all the vivacity and activity of life. It is probable, that their eggs or germs are ever floating in vast numbers in the air, though unseen, awaiting only a proper receptacle, or soil, so to speak, in which at once to grow and exhibit the phenomena of life. We shall point out a few of the most remarkable, and for full information respecting them, refer to Mr. Pritchard's *History of Infusoria, Living and Fossil*, in which are figures of great numbers, and descriptions of all, together with ample information respecting their habits, reproduction, structure, &c.

196. *Volvox globator.* This is one of the largest species, being about $\frac{1}{30}$ of an inch in diameter, and, therefore, easily perceptible by the naked eye. Its appearance is that of a small green globe or ball, moving in all directions, sometimes slowly, sometimes rapidly, rolling over and over, spinning round, or sailing smoothly along. It was first discovered by Lewenhoeck. It is not, however, so strictly an animalcule, as a large family of animalcules, all dwelling most harmoniously together, and united into a globe; for on submitting it to the microscope, it is found to be studded all over with green specks, which are connected together by a kind of network. On examining it with a high power, these specks are seen to be distinct and separate animalcules, each possessing a red "eye" and two cilia, and connected with those which are around them by fine and delicate filaments. Within one of these globes there are probably thousands of these separate animalcules; for besides the numbers which cover its surface as with a fine net, six or eight smaller and similar globes are enclosed within the larger one, each similarly enveloped with its mantle of living beings. The globe bristles with the cilia of its component animalcules. It is found most abundantly during spring and summer, in ponds, clear pools, and stagnant water, and often in the same water with young lizards and frogs. Infusions of hemp-seed are said to abound with it. Very recent observations on the *Volvox*, by Professor Williamson of Manchester, have led him to the conclusion, that this must (like the *Diatomaceæ*) be in future excluded from the ranks of the animal kingdom, and be accounted as a vegetable.

197. *Vorticella* (Fig. 40). This most graceful and elegant animalcule is very commonly to be found attached to the roots of duckmeat. It resembles a minute transparent bell, the rim of which is fringed with cilia, and the small end of which is attached to a stem, which is capable of being either extended to a considerable length, or suddenly contracted into a close coil. These animalcules are social, and a number are almost always clustered together. In some species they have a common stem, from which they ramify like branches on a tree. They will afford a most interesting object for study to the microscopist, and to watch them with their transparent cables swimming at full length in search of food, and, if alarmed or disturbed, coiling them down close to their anchorage with the rapidity of thought, then again gradually uncoiling and extending themselves as before, their cilia all the

while in rapid motion in search of food, will always be a beautiful and attractive spectacle. They propagate by self-division, each bell, when full-grown, gradually dividing into two in the direction of its length. One or both then separate from the stalk, and after swimming about free for a time, the solitary bell attaches itself to some fixed spot by the base, which speedily extends into an elastic stem, and becomes the nucleus of a new colony. The numerous "stomachs" above mentioned, may be well observed with a high power in this animalcule, and we shall here quote Dr. Mantell's account of his experiment on them, to give a clear idea of this part of their structure, and to point out the method of making similar observations :—"I place a drop of a solution of carmine in the water, between the plates of glass containing these animalcules: the fluid in which they are floating now appears turbid, and full of grey particles, which are thrown into rapid motion by the vibrations of the cilia, and currents are seen passing to and fro from the mouths of the animalcules. In a few minutes the water becomes clear, and several round spots of carmine are apparent in the body of each animalcule. We have, in fact, caused their little stomachs to be filled with colouring matter, and can now distinguish their number and arrangement. If the body of the animalcule were a mere cavity, it is obvious that the carmine must have been collected into a single ball or mass, but this is not the case ; on the contrary, the colour appears in distinct round spots, from having accumulated in globular cells, and by careful investigation, the tube connecting these cells may be detected." This method of feeding animalcules with carmine and indigo, we ought to state, has been long in use.

198. *Stentor.* This is commonly termed the Trumpet Animalcule, from its resemblance, when fully expanded, to a trumpet. Its whole body is covered with cilia, and the expanded mouth is thickly fringed with them. It has no stalk, but attaches itself, like a leech, to decayed sticks, &c. It is one of the largest of the polygastrica, and is very voracious. Its numerous stomachs may be readily observed by feeding it with carmine or indigo, as described above. They vary in colour, and may be found blue, red, green, yellow, or brown ; and sometimes they cluster so thickly together as to appear to the eye like a small mass of coloured jelly. They are commonly found in ponds and stagnant waters, attached to stones, sticks, leaves, &c.

But we may not extend these remarks. Every possessor of a microscope may and should hunt for infusoria, if he wishes for some of the richest treats the instrument can give him. A few sage leaves, hemp-seeds, a small bunch of hay, tea leaves, and many other vegetable substances, if steeped in water for a few days till they begin to decompose, will be certain to afford plentiful sources of infusoria, and in all probability different species will be found in different infusions; and even the same infusion will exhibit several changes of species according to the time it has been kept. In ponds and ditches, pools and lakes, a much greater variety will be found, however, than in any infusions, and of species which will never be found in such situations. A few common wide-mouthed phials with corks, and a long stick, to which either a large spoon or a fine linen net can be attached at pleasure, will be all that is required to collect them. A pond on the leeward side will have an accumulation of floating leaves and scum of organic matter which will afford an abundant source of infusoria; the other side will afford different kinds, less commonly. The roots of duckmeat, frogbit, hornweed (*Ceratophyllum*), and a variety of water plants, may be examined with pretty good certainty of success. In fact, wherever there is water and decaying vegetable matter present, they are sure to be found. We have already stated that between two and three thousand species have been described, but the numbers in which these occur, even within a very small space, utterly baffle conception, and foil the grasp of the most expansive mind. We have near us at this moment a jar, a few inches in diameter, containing some sprigs of *Hyoscyamus niger* with calyces steeping to prepare for skeletons, and on the surface of the water a scum has collected containing two species of animalcules, the individuals of which are to be numbered by millions. The infusoria which we have now been noticing are best observed as living objects; but they may also be mounted in cells of fluid, as directed in the chapter on mounting. Mr. Thwaites's fluid, or Goadby's fluid, A. 2 (sect. 31), are the best for this purpose.

199. The shelled or loricated animalcules, including the *Diatomaceæ* already alluded to in speaking of the *Algæ* (sect. 104) next come under our notice. In the preceding account of the infusoria, we have only mentioned those which have soft bodies without any protective hard covering; but there are

large numbers of species which have a shield-like shell, usually silicious (Figs. 41, 42, 43, 60, 61, 62), which, when the animal which it covers dies, is indestructible by the ordinary agents of decay, and though it falls to the bottom and is buried in the mud, is still preserved there. These loricated (from *lorica*, a shell) infusoria, as they are termed, are, to the microscopist, amongst the most interesting of objects, and we purpose devoting a small space to them, as a large proportion of them are supposed by some to belong to the vegetable rather than the animal kingdom. Ehrenberg, Pritchard, Bailey, Schleiden, and others regard them as animals; Kutzing, Carpenter, Hooker, Harvey, Hassall, and others, as vegetables. Where such eminent men differ, we cannot presume to give any positive opinion. They appear to form, strictly, a border territory, almost a neutral ground, between the two great sections of organic nature, embracing characters of both. Of the two, we are inclined to think that the animal character preponderates, and therefore describe them here. They are as generally diffused as the soft-bodied infusoria, being found almost everywhere—salt and fresh water alike abounding with them. We cannot here enter into lengthened details respecting the species thus curiously furnished, but purpose giving general directions for finding and mounting them.

200. Mr. Pritchard's *History of Infusoria*, and Mr. Smith's *Diatomaceæ*, will supply figures and descriptions of the various species. Whenever a scum is perceived on the surface of a pond or of stagnant water, especially if coloured or dust-like in its appearance, it is worth examining, and will probably afford a rich harvest of *Diatomaceæ* and *Infusoria*. Brown or green spots on submerged sticks, stones, stems, or leaves of water plants, especially in mountainous rivulets, will often be found to be rich deposits of specimens. A mouldy or dusty appearance on leaves or stems under water, or on confervæ or marine algæ, especially the thread-shaped kinds, will usually be found to consist of them. On stagnant water an iridescent film may often be seen, as if a very thin film of oil were floating there. This will often be found to be rich in various species. An abundant, and to a dweller or visitor on some parts of the coast, an easily attainable source of the marine shelled infusoria is the stomach of the scallop (*Pecten*), which feeds on them, and which will be found to contain a rich harvest of most beautiful forms. Mr. Reade, in a paper read

before the Microscopical Society, has pointed out that the stomach of the oyster frequently abounds with these organisms, and that different species are found both at different seasons, and in oysters from different parts of the coast. The stomach of this mollusc usually contains swarms of monads and other infusoria, and among them many loricated ones. Marshes in the neighbourhood of the sea, or the deltas of rivers, or the shallow pools left by the retiring tide at the mouths of our larger rivers, are good spots where to search for them. At water-falls and in various streams they will assume the form of cushion-like tufts, or spread over the stones like delicate velvet. On mud, especially the mud of estuaries, they form a filmy stratum on its surface. Their colour is usually a yellowish brown of a greater or less intensity, varying from a light chestnut in individual specimens to a shade almost approaching black in the aggregated masses. In the water cisterns which are supplied by the chief water companies of London, they may be found in plenty in the deposit which accumulates at the bottom, especially those supplied by the New River, East London, Kent, and Grand Junction Companies. In the black mud of the Isle of Dogs, half-way between high and low water mark, they may be detected in profusion.

201. In collecting, the student may avail himself of the tendency which the *Diatomaceæ* possess, in common with all growing plants, to make their way towards the light; all that is necessary being to place the gathering which contains them in a shallow vessel, and leave them undisturbed for a sufficient length of time in the sunlight, and then carefully to remove them from the surface of the mud or water. The dredge is also useful in procuring many which could not otherwise be obtained. The stomachs of the crab, lobster, sole, turbot, and whelk, also often contain rare species.

They may be mounted in Canada balsam; but it will often be necessary to digest them in strong nitric acid for a time to free them from all extraneous matter, after which water may be freely added, and, after standing an hour or two, carefully poured off and fresh water added. These washings must be repeated till the infusoria are quite clean. The greatest care, however, must be taken not to pour away any of the sediment of shells with the water, and also to allow a sufficient time to elapse after each affusion of water, to permit them perfectly to settle to the bottom. This will take a considerable time, on account of their extreme minuteness and lightness. See the directions for preparing guano (sect. 206).

202. The following observations, by G. Shadbolt, Esq., in the *Quarterly Journal of Microscopical Science*, are so valuable, that we are induced to extract them. They are worthy of attentive study, not only as pointing out very clearly some rich localities for infusoria, &c., but also as indicating the more usual characters by which their presence may be recognised by the unassisted eye, and the precautions to be used in collecting them. Brooks, ponds, marshes, and bogs being their chief source (as also of the *Desmidieæ*), it will be apparent that to spend a day in collecting with any comfort, it will be necessary to make some provision for keeping the feet dry, for which a pair of India-rubber galoshes, or, better still, a pair of waterproof fishing boots is necessary; but without one or the other the work is by no means pleasant:—

"A dozen or two of small bottles, made of glass tubing, about $\frac{1}{2}$ an inch in diameter, and without necks, and from one to two inches in length, are the most convenient depositories, if the specimens are ultimately intended for mounting; and it is advisable also to take two or three wide-mouthed bottles of a larger size, holding from one to two fluid ounces, an old iron spoon, a tin box, some pieces of linen or calico, two or three inches square, a piece of string, a slip or two of glass with the edges ground, such as are used for mounting objects; and lastly, a good and pretty powerful hand-magnifier. Two Coddington lenses mounted in one frame of about $\frac{1}{2}$-inch and $\frac{1}{10}$-inch focal power, are specially convenient.

"Perhaps it will be as well, in pointing out a few localities, to describe some that I have actually visited, with the means of access, and the appearance of the various species, *en masse*, that I have met with.

"Swanscombe salt-marsh will be found well worth a visit, and it can be reached by steamboat or railway from London to Northfleet. On quitting the railway station, make towards the alms-houses on the top of the hill, and, arriving at the road, turn to the left, descend the hill, and cross a sort of bridge over a somewhat insignificant stream. Continue along the main road a little farther, to a point where it begins to ascend again, and diverges to the left towards the railway; here quit it, taking your course along an obscure road, nearly in a direct line with the main one: passing a wind-mill on the right hand, and continuing till you arrive at a still more obscure road, turning off to the right, which road appears as if made of the mud dredged from the bottom of the river, and partially hardened. This is Swanscombe salt-marsh, and the road first described leads towards Broadness Beacon. On either side is a sort of ditch; one containing salt, or very brackish water, the other filled with a sort of black mud, about the consistence of cream, the surface being in parts of a slaty grey, with patches here and there of a most brilliant brown colour, glistening in the sunshine, and presenting a striking contrast to the sombre shade. By carefully insinuating the end of one of the slips of glass under this brilliant brown substance, and examining it with the Coddington, it will probably be found to consist of myriads of specimens of *Pleurosigma* (*Navicula*), *angulatum*, or *balticum*, or some other species of this genus (Fig. 62). The iron spoon is now useful, as by its aid the brown stratum, with little or no mud, can be skimmed off and bottled for future examination. On the surface of the water, in the other ditch, may be noticed a floating mass of a *dark-olive* colour, which to the touch feels not unlike a lump of the curd of milk, and consists of *Cyclotella meneghiniana*, and a *Surirella* or two imbedded in a mass of *Spirulina Hutchinsiæ*, and another mass of floating weed, which feels harsh to the touch, proceeding from a quantity of *Synedra*, closely investing a filamentous alga, and elsewhere *Meloseira nummuloides* (*Gallionella*).

"In a trench by the sea-wall, as it is termed, is a mass of brown matter, of a shade somewhat different to any hitherto observed, adhering to some parts of the trench, and having a somewhat tremulous motion on agitating the water. This is a species of *Schizonema*, and it consists of a quantity of hollow gelatinous filaments, filled with an immense number of bright brown shuttle-shaped bodies like very minute *Naviculæ*. It is not necessary to be particular about collecting the specimens free from mud, as the filaments are so tough that the mud can be readily washed away by shaking the whole violently in a bottle of water, and pouring off the mud, without at all injuring the specimen. The *Anphisporium alatum* communicates a somewhat frothy appearance to the otherwise clear water, and to get any quantity of this requires a little management; but by skimming the surface with the spoon, and using one of the larger bottles, an abundance may readily be obtained. Between the sea-wall and the river, the marsh is intersected in every direction with a number of meandering creeks, being in some places eight to ten feet deep, though in others quite shallow; but it is exceedingly difficult to make one's way among them, and I have never found them so prolific anywhere, on the few occasions of my visiting the place, as in the parts more away from the influence of the tide. It will be observed that the brilliant brown colour, of a deep but bright cinnamon tint, is one of the best indications of the presence of *Diatomaceæ;* and though this is by no means universal, the variation is most frequently dependent on the presence of something that qualifies the tint. The peculiarity of this colour is due to the endochrome contained in the frustule; and this must in general be got rid of before the delicate and beautiful markings can be made out. But it is highly advantageous and instructive to view them in a living state; and this should be done as soon as possible after reaching home with all specimens procured from salt-water localities, as they rapidly putrefy in confinement, and emit a most disgusting odour, not unlike that arising from a box of inferior Congreve matches. Washing in fresh water, and then immersing in *Kreosote water*, preserves many of the species in a very natural-looking manner; but they are killed by the fresh water, and the endochrome becomes much condensed in the *Pleurosigmata* and other species. The addition of spirit quite spoils the appearance of the frustules, as it dissolves the endochrome.

"There is another salt-marsh a little further down the same railway, at Higham, which it would be well to explore. The most favourable months for procuring *Diatomaceæ* are April, May, September, and October; but some species are found in perfection as early as February, and a few at all times of the year. It must not be imagined that nothing can be obtained in this department of natural history without going some distance from town; but assuredly only fewer and commoner species can be met with nearer. At the West India Docks are *Synedra fasciculata, Gomphonema curvata, Diatoma elongata, Diatoma vulgaris, Surirella ovata,*" &c. In the Serpentine, on the north side, especially near the bridge, more than a dozen species may be found. The fresh-water and brackish ditches in the parish of Milton, near Gravesend, also afford a great variety of species.

203. We now proceed to speak of *fossil Infusoria.* Of course it is only the loricated *Infusoria* and *Diatomaceæ* which can be preserved in a fossil state, as it is only their

silicious shells which do not decompose and decay with extreme readiness and rapidity. It is very remarkable how, in this particular, extremes meet. No animal matter is perhaps shorter-lived or more readily decomposable than the bodies of the *Infusoria;* no animal structures more enduring or indestructible than their shells. The fire which would calcine to lime, or the acids which would dissolve the bone or shell of the superior classes, have little or no effect on them; and their very minuteness shields them in some measure from the almost certain comminution which awaits larger and more conspicuous structures. The vast numbers in which these shells are found not only confounds the imagination, but baffles all calculation. Near Ebsdorf, in the neighbourhood of Luneberg, Hanover, a bed of light silicious earth is found, which consists entirely of the shields of *Infusoria.* This bed of earth is twenty feet thick, and extends a considerable distance, while the separate shells of which it is composed are quite invisible to the naked eye. The towns of Richmond and Petersburg, in Virginia, are built over strata miles in extent, and varying in thickness from twelve to twenty-five feet, of a flinty marl, which is crammed full of the shells of animalcules; so full, that if a little of it be mixed with water, and the least quantity of this be spread on a slip of glass and examined by the microscope, it will be found full of their shields, belonging to many species. Indeed, it is probable that the remains of all the higher animals which exist as fossils throughout the strata of the globe, if collected into one spot, would form a mass insignificant in extent, compared with the immense beds of earth and rock formed entirely of the remains of these minutest of animals. In Bohemia a light white earth occurs in large quantity, consisting almost entirely of the shield-shaped shells of the *Campylodiscus clypeus* (Fig. 41). In Sweden and Norway enormous beds of earth, resembling flour in appearance, are found, and are called *Berg-mahl,* or mountain meal; they consist almost exclusively of very minute infusorial shells, and still retain a portion of animal matter, so that this "mountain meal" is used in times of scarcity to mix with flour for making bread, and is believed to be nutritious. Perhaps the fact discovered by Ehrenberg, with regard to the bed of animalcules beneath Berlin, is one of the most remarkable hitherto placed on record with regard to this wonderful tribe. This bed exists beneath the city itself, and extends to the depth of from twenty to sixty feet in the form of a funnel. It commences about fifteen feet below the surface. Two-thirds of the whole are composed of loricated infusoria, but *alive;* and this life is apparently sustained by the water which drains through the mass. Here, close packed as they are, they live, and apparently propagate; for in one quarter of the city the solidity of the buildings is actually endangered by them, probably on account of their rapid increase. There is said to be a similar bed at Newcastle.

204. We append a list of some of the chief localities where large beds of infusorial earth have been discovered, all of which contain numerous and interesting species. In all cases where foreign matters are mixed with them (and this is usually the case to a greater or less extent), they may be prepared as directed for guano (sect. 206). Mr. Pritchard suggests, however, a simpler method. Gradually but completely dry by heat the earth or sediment in which they exist; then take a glass full of cold water, and strew the powder on the surface of the water; when in a few minutes the earth and sand will sink to the bottom of the glass, and the shells being filled with air, will float on the surface, and may be removed by gently introducing a slip of glass under them.

Dolgelly, Merionethshire; ancient site of a mountain lake.

Lough Island, Reavey, Down, Ireland.

Lough Mourne, Antrim, Ireland.

Mull, Scotland, in a whitish earth resembling marl, in a rough piece of ground at Knock, near Aros, between Loch Baa and the sea. It is very rich in species; fifty-nine are enumerated in a list in the *Quarterly Journal of Microscopical Science.*

Obero, Germany.

Wreathane, Massachusetts.

Rappanhannah Cliff,
Schockhoe Hill, } United States.
Piscataway, Maryland,

Oran, Algeria; very beautiful.

Bilin, Bohemia.

West Point, New York; a fresh-water deposit.

Blue Hill, Maine.

St. Fiora.

Bermuda; very rich in *Coscinodiscus* (Fig. 42), *Triceratium* (Fig. 43), and other beautiful marine species.

It will always be worth while for a microscopical observer in whose neighbourhood there is any peat, or peat-bogs, to examine them carefully. He will very likely find that in cutting the peat, deposits of light, white, pearly, or flour-like matter are exposed. In this case, he may almost rest assured, even before a microscopical examination, that they are composed of the shells of *Infusoria.*

205. Everybody knows that at the mouths of rivers, great deposits of earthy sediment are forming, and that harbours are often much injured or choked by the incessant accumulation of mud and sand; but few suspect that a great part of that mud is neither more nor less than the shells of animalcules, and yet so it is. In the harbour of Wismar, in the Baltic, there is deposited every year more than 200,000 cubic feet of mud; and it has been proved that from $\frac{1}{4}$ to $\frac{1}{20}$ of this deposit consists of the shields of *Infusoria.* In the mud-banks of Pillau infusorial animalcules were found in still larger proportions. The mud deposited by the Elbe, at Cuxhaven, was in like manner found to be composed of animalcules to nearly half its bulk. In the rivers of our own country similar facts have been observed. The mud of the Humber and Orwell abounds with infusorial shells. From east to west, from the Arctic to the Antarctic, is the same marvellous accumulation going on of these minute beings. They have been found abounding in the mud at Erebus Bay, near the South Pole; they are found in the mud at the bottom of the ocean under the equator. The sediment of the Nile owes its fertilizing properties, in part at least, to its teeming with them; and when Dr. Hooker was sailing with the Antarctic expedition, he says, "That between 60 and 80 degrees of latitude, the sea seemed everywhere stained brown, owing to the universal diffusion throughout it of countless myriads of these organisms. Their silicious remains are forming a submarine continent some 400 miles long, by 120 broad. All the soundings over this deposit—and the lead sometimes sunk two feet in the mud—brought up next to nothing besides these shells." To prepare specimens for the microscope of these various deposits, both fossil and recent, the process presently to be recommended for guano may be followed with advantage, except that the diluted hydrochloric acid may be added at once instead of being preceded by several washings.

206. Another very extraordinary deposit of silicious infusorial remains requires a notice. Almost every one is familiar with the fact, that on some of the islands off the coast of *South America* and Africa, immense deposits of guano are

found. This guano is simply the excrement of sea-fowl, which has accumulated on these uninhabited islands for ages and generations, and is now found to be a most fertilizing and profitable manure. This guano is found to be full of some of the most beautiful forms of infusorial shells, and will amply repay some amount of trouble and attention to isolate them from it. How these came there may excite wonder; but there can be little doubt that they were the indigestible remains of the animalcules which molluscs and fish had fed upon; and these in their turn becoming food for the birds, the infusorial shells, indigestible by either, remain and pass away in the excreta of the sea-fowl. The best process for separating them from the animal refuse in which they are imbedded, is that given by Mr. Quekett, which we now quote: "Take any convenient quantity of pure Ichaboe guano, and wash it by repeated affusions of distilled water till the water is no longer coloured, observing after each addition of water that it must be well stirred two or three times, and then allowed to settle for some hours. When sufficiently washed, a small quantity of hydrochloric acid is to be added to the water last used; this dissolves some portion of it with effervescence, and causes a more perfect subsidence of that portion which it does not act upon. After this, allow sufficient time for the deposit to become well settled down, then the clear liquor being poured off as closely as possible, without loss of the sediment, a quantity of strong nitric acid, in the proportion of about two fluid ounces to every ounce by weight of the guano employed, is to be added. A strong effervescence takes place, which is to be assisted by setting the mixture in a warm place, at a temperature of about 200° Fahrenheit, for six hours, during which time the greater part of the guano is dissolved. After allowing it to stand in a cold place for twenty-four hours, pour off the acid liquor as closely as possible, and wash the sediment with an abundance of distilled water. The finer portions of the sediment will contain all the silicious shells of the guano, perfectly freed from extraneous matter. It should be borne in mind in all these cases, that some time should elapse before the acids or the distilled water are poured off from the sediment, in order that solid matter may subside, as it has often happened that the most beautiful of the infusoria have been thrown away with the water employed to wash them."

207. One more source of fossil animalcules must be noticed, viz., in flints. The flints which abound in the chalk, especially in the south of England, are found very commonly to contain

the remains of animalcules of the genus *Xanthidium*. They resemble a ball, from the surface of which spines project in every direction, and these spines are forked at the tip. In order to find them, all that is necessary is to chip off with a hammer the thinnest possible flakes of the flint, and examine them with the microscope, previously dipping them in spirit of turpentine, to render them very transparent. A half-inch achromatic lens will show them well. The specimens which are reserved for mounting may be laid aside, and, when convenient, mounted in Canada balsam. Till so mounted, however, the greatest care should be used in examining them by the microscope, that the object-glass may not, in adjusting the focus, by any accident come in contact with it, as the sharp edges of the flint would probably irreparably damage the lens.

CHAPTER IX.

MISCELLANEA.

208. *Inorganic objects.* Many minerals in small fragments afford pretty opaque objects for low powers; but beyond their beauty, much information cannot be derived from them, as they are devoid of structure. The following are perhaps some of the best:—

Copper pyrites.
—— moss.
Garnet sand.
Crystallized tin.
Ruby copper.
Copper mica.
Zeolites.
Micaceous sand.
Peacock copper.
Native copper.
Prismatic feldspar.
Red antimony ore.
Mica, various varieties.
Lapis lazuli.
Fibrous malachite.
Red orpiment.
Copper sand.
Red silver.
Green sand.
Granites, various.
Crystals of sugar of milk.

Thin sections of some stones may be viewed as transparent objects.

Ærolite.
Moss agate.
Oolite, Ketton.
—— Bath.
Stalactite (Sulphate Barytes).
Oolite, Portland.

A few fabrics should also be mounted. They may be viewed sometimes as opaque—sometimes as transparent. The coarseness of their structure serves as an admirable example of the contrast between the works of man and those of the great Creator. The form of the fibres of linen and cotton should be examined; by this test the mummy cloth of the Egyptians has been proved to be linen, showing that they were unacquainted with cotton fabrics. It is not necessary to give lists of these; we may just mention lace, gauze, muslin, velvet, lawn, ribbon, mousseline de laine, &c., &c.

209. *Crystallization of Salts.* A more beautiful sight can scarcely be imagined than the process of crystallization, actually proceeding under the microscope. Crystals of the most elegant configuration are seen actually forming beneath the eye, the point advancing with a steady motion across the field of view, while from its sides branches start off continually, often exhibiting a resemblance to the most graceful foliage, or, still more strictly, to those beautiful and fantastic crystallizations of ice which so often adorn our window panes on severe and frosty mornings. The method of viewing these crystallizations is exceedingly simple. A small quantity of the proper salt is taken, and just enough water added to produce a saturated solution (*i.e.*, one in which the water has dissolved as much as it is capable of taking up). A drop of this being placed on a clean slip of glass, and spread out, is then to be slightly warmed, and instantly placed under the microscope, which should previously have been adjusted as to illumination and focus. (An inch or ¾-inch object-glass will be best.) The crystallizations will now be seen to shoot across the field of view, and to form the beautiful figures. In the following list of the most interesting crystals for this purpose, we give the proportions which make a saturated solution. The easiest way to prepare them is to pour on the salt, previously bruised small, the proper quantity of boiling water, stir it with a slip of glass, when it will almost instantly dissolve, and will be ready for use at any time.

Nitrate potass (saltpetre), ...	3	parts	to	10	of water.
Muriate of ammonia (Sal ammoniac), ...	3½	,,	,,	10	,,
Bichromate of potass, ...	1	,,	,,	10	,,
Muriate of barytes, ...	3½	,,	,,	10	,,
Citric acid, ...	13	,,	,,	10	,,
Oxalate of ammonia, ...	4	,,	,,	100	,,
Spirit of camphor used as a solution of salt.					

If a small quantity of gum-water, solution of starch, gelatine, &c., be mixed with the saline solution, the crystals will be curved, like drooping feathers, which offer a pleasing variety.

210. *Polarized Light.* For the method of obtaining polarized light, and applying it to microscopic purposes, we refer the reader to sect. 10. Neither can we in this place enter into the theory of the polarization of light, inasmuch as it is very difficult to render it popularly intelligible, and the attempt would demand a larger space than we can devote to it. All we propose here is to point out the methods best adapted for mounting objects to be viewed by the polarizing microscope, and to give a list of those which are most beautiful and interesting. Where the objects are crystalline, spread a thin film of the saturated solution upon a glass slide made perfectly clean, and allow it to evaporate and become quite dry, taking care that no dust is allowed to settle upon it. This may be done on one of the bevelled No. 2 slides, and, when quite dry, all that is necessary is to place another slip on, and mount it as directed in sects. 41, 42. Another method is, in a similar manner to crystallize a drop of the solution on a No. 1 slide, and then pour on it a drop of Canada balsam previously heated (if old and hard, it may be thinned with a little turpentine or ether), and cover with a piece of thin glass, taking every care to exclude air-bubbles. Castor oil is also a good medium, full directions for which have been given in sect. 37. The following are the best salts for the purpose. For most of the following lists we are indebted to Mr. Quekett's work :—

Acetate of copper.
Bichromate of potass.
Borax.
,, crystallized in glacial phosphoric acid.
Boracic acid.
Borate of ammonia.
Carbonate of lime.
Chromate potass.
Sulphate of cadmium.
,, copper.
,, nickel.
Oxalurate of ammonia.
Oxalurate of ammonia with plate of selenite.
Chlorate of potass.
Cholesterine.
Citric acid.
Sulphate magnesia.
Murexide.
Oxalate ammonia.
,, chromium.
,, lime.
,, soda.
Tartrate of lime.
Triple phosphate.
Uric acid.
Quinidine.
Nitrate ammonia.
,, potass.
,, baryta.
,, lead.
,, soda.
Oxalic acid.
Phosphate soda.
Sugar.
Sugar of milk.
Salicine.
Acetate of zinc.
Asparagine.
Ammonio-phosphate of magnesia.

211. The following must be viewed in thin sections: Agate, Brighton pebble, Satin spar. *Raphides* have been described, and the method of obtaining them detailed in sects. 63, 64, and many afford interesting polarizing objects, especially those of hyacinth, onion, and rhubarb.

The following may be mounted dry:—

Starch; potato.
,, arrow-root.
,, Indian corn.
,, tous-les-mois.

Gun cotton.
Raw cotton.
,, flax.
Scale, eel.

Scale, sole.
Human skin.
Fibres of sponge.
Raw silk.

The following should be mounted in balsam. Of those marked thus * thin sections only must be used:—

* Hoof of ass.
* ,, camel.
* ,, horse.
* ,, ox.
* ,, sheep.
* Horn of rhinoceros.
* ,, antelope.
* ,, ox.
* ,, sheep.
Silicious cuticle, bamboo.
,, Equisetum
See also sect. 67.

White hairs of the horse (interlaced.)
* Quill of porcupine.
* ,, Echidna.
* ,, condor.
* Tendon, human.
* ,, ostrich
* Skin, elephant.
* ,, crocodile.
* ,, rhinoceros.
Hairs of Deutzia.
,, Elæagnus.

Hairs of olive.
Spicules of Gorgonia.
* Whalebone.
Wing-case of beetle (Animal matter of.)
Bone of cuttle-fish.
Palate of whelk.
,, limpet.
,, Nassa.
,, Paludina.
,, Cyclostoma.

The following zoophytes, mounted either in balsam or fluid, are beautiful objects with selenite beneath them:—

Sertularia operculata.
,, filicula.
,, abietina.

Plumularia falcata.
Flustra truncata.
Cellularia avicularia.

Many of these require a thin film of selenite placed beneath them to bring out the full beauty of the object. See sect. 10.

212. *Books.* The present work being only intended as a kind of A B C for the beginner in microscopical science, and especially for those who are unable to afford the larger and more expensive works and instruments, there were two essential requisites for it, conciseness and cheapness. These have necessarily compelled a brief and very summary view of the various departments of the animal and vegetable kingdoms; and in those details which we have given, our aim has been just to point out only such particulars as would lead the observer to a tolerable idea of the nature and character of the object under review. Every one, however, who pursues this study, will wish for more detailed information on each point than we have been able to embody in a work taking so wide a scope, and in such small limit as the present. We purpose, therefore, here, to give a list of the most useful works, where the inquirer may find the full information he requires. Many of these works are very costly, and therefore probably beyond the reach of purchase by most of those who will consult this manual. Such, however, in large towns at least, have pro-

bably access to some good public library, where some, if not most of them, may be found. We need scarcely name the Library of the British Museum as a place where they may all be seen, free of expense, by any one who has the opportunity of going thither, and has taken the steps necessary to gain admission.

GENERAL TREATISES.

Treatise on the Microscope, by John Quekett. 2d edition. 21s.
  This is the standard work on the subject, and contains ample details with respect to the best Microscopes and Apparatus, Mounting, &c.
Lectures on Histology, by John Quekett. 2 vols. 8vo.
  A very valuable work on animal and vegetable structure as exhibited by the Microscope.
Microscopic objects. 1847. (Understood to be by Mr. Pritchard.) 5s.
  Contains a list of 2000 objects, with remarks.
Baker's Employment for the Microscope. 2 vols. 8vo.
Adams's Treatise on the Microscope. 4to.
  These are both old works, and their information on instruments is quite out of date; their accounts of objects are still valuable, however.
The Microscope, by Jabez Hogg. 1854. 6s. Ingram and Co.
Hannover on the Microscope. Translated by Mr. Goodsir. S. Highley.
The Microscopist, by Dr. Wythes.
The Microscope and its Revelations, by W. B. Carpenter, M.D. 1856. A very excellent work. 12s. 6d.
Griffiths & Henfrey's Micrographic Dictionary, thick 8vo. 50s. (A Dictionary of Microscopic Objects.)
How to Work with the Microscope, by Dr. Lionel Beale. 5s.
Treatise on the Microscope, by Sir D. Brewster. 6s.
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213. Here we close our synopsis of microscopical study; but we cannot refrain from adverting to the magnificent views which it unfolds to us of the greatness, the wisdom, the power, and the goodness of the Divine Creator. The telescope gives us a view of His greatness in one direction. It shows us that our world is but one among a group, many of which are larger than itself, and every one of which, while moving swiftly in its appointed course at a speed and a distance which the human mind fails clearly to picture, possesses features peculiar to itself. Yet this group of worlds, of which ours is one, great, vast, and to us almost incomprehensible in its magnitudes, is only a speck among myriads of stars, each as great, if not greater than the sun, which is the glorious luminary of our system, and many of which form systems on the grandest and most magnificent scale. But, numerous as are the visible stars, those which to our unassisted vision remain invisible are so vastly more numerous, that they defy every attempt of the human mind to count and classify them. The telescope reveals to us the sky as if powdered with worlds. And if we use the highest powers with which that instrument can be furnished, other and yet other galaxies of worlds come into view, which before, even to the telescope, seemed only pale clouds of misty light. If we can grasp any idea of so unutterably vast a scene, and then from it turn our thoughts to Him who summoned the whole into existence by the word of His mouth—"for whose pleasure they are and were created"—surely our thoughts of His majesty, infinity, and omnipotence must receive a vast

though all inadequate extension ; and surely a reverence for such a Being profounder than we have felt before must pervade our minds.

But if now we turn back to our own world—that merest speck in the universe—and call to mind its vastness with regard to ourselves, the myriads of tribes of animals and plants which populate so densely its surface, filling the air, the sea, the waters, and the land with organized beings in vast variety and of wonderful structure, we find our minds as completely baffled in endeavouring to comprehend His works and operations in this limited spot, as in the gigantic expanse of the heavens. The geologic revolutions which have in the ancient periods passed over our globe, confound us by the grandeur of the scale on which they have taken place, and by the enormous length of the cycles required for the gradual operation of the causes which have produced them. And, in like manner, if we contemplate the great chain of animal existence, from man at its head, down to the infusory animalcule, which requires one of the highest powers of the microscope to detect it, and which is nevertheless furnished with nutritive and locomotive organs, we feel that we must attribute all this ceaseless variety to Him who is wonderful in counsel, and excellent in working. And if, following the course of study we have endeavoured to sketch out in the preceding pages, we investigate the minute structure of these various beings, we find that all are indeed wonderfully made ; and every object we examine reveals to us some marvellous structure, exquisitely adapted to fulfil that purpose or function for which it is intended. In all these points, we find that every plan adopted is perfect in its kind, and that no better can be imagined to answer the purpose for which it is designed. And when, too, we mark the inconceivable numbers, especially of the smaller and infusorial animals, and notice their amazing fecundity, not less does it excite our astonishment that the balance is so accurately preserved—that some do not multiply to the exclusion or extinction of others ; but that while all the species are preserved, each has its limit, both of territory and of multiplication. Again, the presence of an all-wise and all-pervading Providence is most wonderfully manifest in giving to all these almost infinite myriads food in abundance, yet so apportioning all, that while some are the scavengers, fulfilling their appointed mission by clearing the earth of those decaying animal and vegetable substances which everywhere abound, some restrain, by their predatory habits, the undue fecundity and multiplication of others; and thus, while all are duly cared for, there is no superfluity or waste. Once again, the beauty which is so profusely exhibited in all, is most astonishing, not only in those forms of organic and inorganic nature which meet the eye, but still more remarkably in their intimate structure, which nothing but the microscope can reveal to us. More exquisite beauty, more graceful form, more elaborate ornament is nowhere to be seen than in some of the minutest members and structures of the animal and vegetable kingdoms. In the view of all this, and turning our thoughts to Him who created and adjusted all, and who upholds and still governs all, what conceptions shall we form of His wisdom and power? The most gigantic human intellect is bewildered and lost in the contemplation. How much more, then, when we recollect that He who has thus richly and marvellously furnished this earth is He who governs that immense wilderness of worlds to which we have alluded above. With tenfold power does the exclamation of the Psalmist force itself upon our thoughts, "What is man, that thou art mindful of him!" Yet of *us* this great and holy Being *is* mindful; He has singled us out for His highest display of wisdom and goodness; and may it be our happiness and wisdom, while delightfully engaged in studying some of His works, to be yet more diligent students of that revelation which He has been pleased to make to us in His holy word; that while admiring and adoring observers of the wonders of His works in creation, we may by faith in that Redeemer whom He has sent to take away our sins, and by the teaching of His Holy Spirit, attain that wisdom which cometh from above. This alone can fit us for the right employment of life, and prepare us to meet death calmly and cheerfully. This alone can give us a safe hope of an eternity of happiness, where the mind, freed from every clog and imperfection, with capacities and powers vastly expanded, shall be able to comprehend, to enjoy, and to praise the wisdom, power, and goodness of the Divine Being in His works and ways, to an extent and with an enjoyment here all unknown.

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